This report was funded by the Bonneville Power Administration (BPA), US. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

For additional copies of this report, write to:

Bonneville Power Administration
Public Information Center - CKPS-1
P.O. Box 3621
Portland, OR 97208

Please include title, author, and DOE/BP number from the back cover in the request.

EVALUATION OF JUVENILE FISH BYPASS AND ADULT FISH PASSAGE. FACILITIES AT WATER DIVERSIONS ON THE UMATILLA RIVER

ANNUAL REPORT 1994

Prepared by:

Suzanne M. Knapp

Oregon Department of Fish and Wildlife

Cooperators:

Oregon Department of Fish and Wildlife
Confederated Tribes of the Umatilla Indian Reservation

Prepared for:

U.S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-3621

Project Number 89-024-01
Contract Number DE-BI79-89BP0 13 85

January 1995

CONTENTS

EXECUTIVE SUMMARY

We report on our progress from October 1993 through September 1994 in evaluating juvenile salmonid bypass facilities and juvenile salmonid passage through ladder facilities, and investigating passage conditions for juvenile fish at diversion dam facilities on the lower Umatilla River in northeastern Oregon. We also report on our progress in evaluating adult salmonid passage at and between dams on the lower Umatilla River and upriver migration using radio telemetry. These are the study objectives addressed.

1. Report A (ODFW): To evaluate the juvenile salmonid bypass facilities at Feed and Furnish canals, juvenile salmonid passage through fish ladders at Stanfield, Feed Canal, Westland, and Three Mile Falls dams, and the juvenile salmonid trap and haul procedures at Westland Canal. To investigate passage conditions at all passage facilities.

2. Report B (CTUIR): To examine the passage of adult salmonids past diversions in the lower Umatilla River and their movement in the upper river after transport, using radio telemetry, and to assess factors for successful homing.

These studies are part of a program to rehabilitate anadromous fish stocks in the Umatilla River Basin, including restoration of coho salmon *(Oncorhynchus kisutch)* and chinook salmon *(Oncorhynchus tshawytscha)*, as well as enhancement of summer steelhead *(Oncorhynchus mykiss)*.

Report A

Our evaluation of (1) the juvenile fish bypass facilities at Feed and Furnish canals, (2) juvenile fish passage through ladder facilities at Stanfield, Feed Canal, Westland, and Three Mile Falls dams, and (3) juvenile fish trap and haul procedures at Westland Canal; and investigation of (4) juvenile fish passage conditions at Stanfield, Feed Canal, Westland, Maxwell, and Three Mile Falls dams and their associated canals produced the following highlights:

1. Yearling spring chinook salmon passing through the entire screening facility at Feed Canal and trapped at the bypass outlet received statistically significant injury, although the magnitude of this injury was not large; injury to fish passing through the adult fish ladder was non-significant.

2. Recapture of spring chinook salmon passing through the Feed Canal screening facility averaged 26.9% during our noon to dusk collection period. Median passage time through the adult fish ladder was 4.8 minutes; mean recapture was 58.7%.

3. Overall screening efficiency of the 10 Feed Canal screens was 99.95%. Most leakage occurred at Screen 3; mean length of entrained fish was 63 mm.

4. We used a new meter and a new technique in 1994 to measure screen velocities. Approach velocity at the Feed Canal screens was lower at upstream Screens 1 through 3 than at downstream Screens 4 through 10, but fairly uniform among depths. Approach velocity criteria for salmonid fry (0.4 feet per second [fps]) and fingerlings (0.8 fps) was met at 42% and 98% of the sampling locations, respectively. Sweep velocities at the drum screens ranged near 1 fps to 2 fps, except at Screen 1 where they were abnormally low. Mean velocity at the bypass channel was 2.24 fps.

5. Subyearling fall chinook salmon did not incur statistically significant injury passing from the canal headgates to the terminus of the bypass pipe at Furnish Canal, or through the fish ladder at Stanfield Dam.

6. Median travel time (50% recapture of released fish) of subyearling fall chinook salmon was 2.03 hours from the Furnish Canal headgates to the bypass channel (0.6 miles), 0.31 hours from the bypass channel to the terminus of the bypass pipe, and 12 minutes through the fish ladder at Stanfield Dam. Mean recapture was > 90% at the canal and 72.5% at the fish ladder.

7. Overall screening efficiency of the seven screens at Furnish Canal was 99.99%; one fish leaked at Screen 7 (60 mm).

8. Screen approach velocity criteria for salmonid fry and fingerlings was met at 56% and 100% of the screen sampling locations at Furnish Canal, respectively. Approach velocity tended to be highest at the 80% submerged screen depth. Sweep velocities at the screens ranged from 0.97 fps to 1.65 fps. Mean velocity at the bypass channel entrance was 2.65 fps.

9. Injury to subyearling fall chinook salmon was statistically significant as they passed through the auxiliary water section of the fish ladder at Westland Dam; injury to fish moving through the passage section of the ladder was non-significant.

10. Median travel time for subyearling fall chinook salmon moving through the passage side of the fish ladder at Westland Dam was 0.12 hours, compared to a 0.36-hour median travel time through the auxiliary water side. Mean recapture was 95.8% for passage-side fish and 89.3% for auxiliary water-side fish.

11. During trap and haul loading procedures for juvenile salmon at Westland Canal, we did not detect statistically significant injury caused by fish crowding, pump-loading, or pescalator-loading. Transport time through the pescalator for all test fish was 36.0 minutes.

12. Approach velocity criteria for salmonid fry and fingerlings was met at 90% and 100% of the sampling locations at Westland Canal drum screens, respectively; approach velocities were fairly uniform among depths. Most sweep velocities were higher than 1.20 fps and slightly lower at the 80% depth than at shallower depths. Mean velocity at the bypass channel entrance was 2.10 fps.

13. We did not detect statistically significant injury to juvenile salmonids passing through various portions of the east-bank fish ladder at Three Mile Falls Dam. Modifications to the fish exit gate may have alleviated some of the injury problems.

14. Water velocities upstream of the fish exit gate at Three Mile Falls Dam were highest at the water surface (1.49 fps) and side transects (1.33 fps and 1.09 fps); average midgate transect velocities were lower (0.88 fps) due to a midchannel vertical beam. Velocities collected from one, l-foot-depth location upstream of the auxiliary water diffuser averaged 0.54 fps.

15. Approach velocities at the West Extension Canal drum screens met criteria for both salmonid fry and fingerlings, although the bypass channel was closed. Mean sweep velocities were highest at Screen 1 (0.71 fps) and lowest at Screen 4 (0.51 fps).

16. The underwater video camera imaged at depths of 5 feet to 6 feet, although turbidity restricted viewing distance to 2 feet to 4 feet. Problems with condensation also occurred, but successful imaging was possible.

17. Approach velocity criteria for salmonid fry and fingerlings was met at 85% and 100% of the sampling locations at the Maxwell Canal drum screens, respectively. Mean sweep velocity increased from 0.41 fps at the upstream screen to 1.01 fps at the downstream screen close to the bypass channel entrance where mean velocity was 2.24 fps.

18. Facility monitoring revealed periodic problems with debris, silt, gravel deposition, low river flows, and improper facility or canal operations. Smolt loss continued to occur at the Westland Canal fish separator. The modified Westland bypass pipe functioned well.

19. We recommend placement of additional staff gauges and drum screen side bands at several facilities, regular removal of debris, correct canal and facility operations, improved drum screen bottom seal designs, and pump-loading of juvenile salmonids at Westland Canal.

Report B

Our evaluation of adult salmonid passage and movement, with and without lower river transport, and determination of migration timing and flow needs for homing produced the following highlights:

1. Radio-tagging of three fall chinook salmon, five coho salmon, 23 summer steelhead, and six spring chinook salmon occurred at Three Mile Falls Dam from late October 1993 to late April 1994 for the purpose of evaluating passage at and between lower river diversion dams.

2. Two of the three fall chinook tagged successfully migrated over Westland Dam and one of these fish continued migrating up to Feed Canal Dam. The third fish remained in the lower river.

3. Four of the five coho salmon were successfully tracked; they remained below River Mile (RM) 19.3.

4. Fifteen of the 23 tagged summer steelhead were successfully tracked. An average of 25 days was required to pass from Three Mile Falls Dam to above Stanfield Dam (range of 120 days to 2 days). Migrational behavior was related to seasonal time of entry into the river.

5. Average passage times for summer steelhead (hours:minutes) at Westland, Feed Canal, and Stanfield dams were 1:30, 48:54, and 1:23, respectively. About half of the fish used the fish ladders at Feed Canal and Westland dams; 14% migrated through the ladder at Stanfield Dam.

6. Migration time for summer steelhead between dams (hours:minutes) was 5.37 from Westland Dam to Feed Canal Dam (1 mile) and 33:00 from Feed Canal Dam to Stanfield Dam (4.2 miles).

7. Delay in summer steelhead migration at Feed Canal Dam occurred at flows ranging from 400 cubic feet per second (cfs) to 1,200 cfs. Water temperatures below 42 F appeared to slow fish movement.

8. Five of the six tagged spring chinook salmon were successfully tracked to above Stanfield Dam with an average migration time of 12 days (range of 6 days to 24 days).

9. Average passage times for spring chinook salmon (hours:minutes) at Westland, Feed Canal, and Stanfield dams were 9:14, 11:58, and 0:44, respectively. Sixty percent of these fish used the fish ladder at Westland Dam; about 20% used the fish ladders at Feed Canal and Stanfield dams.

10. Flows < 200 cfs at Westland Dam appeared to cause delay for spring chinook salmon. Delay at Feed Canal Dam occurred regardless of flow levels, which ranged from 330 cfs to 1,221 cfs.

11. For monitoring movement following transport, 11 summer steelhead and nine spring chinook salmon were radio-tagged at Three Mile Falls Dam and transported to upriver release sites. Eight each of the summer steelhead and spring chinook salmon retained their tags following release and were successfully tracked.

12. Summer steelhead transported upstream traveled an average of 6.2 miles per day compared to 6.0 miles per day for non-transported fish.

13. Spring chinook salmon traveled an average of 4.8 miles per days following transport and 8.2 miles per day when not transported.

14. Umatilla origin fall chinook salmon are in the proximity of the Umatilla River in late August and early September, but time of entry into the river varies from early October to late December when flows exceed 150 cfs.

15. Weighted average homing rates were similar for acclimated (54.5%) and direct release (56.3%) fall chinook salmon from 1987 to 1990 brood

years. For these same brood years, stray rates ranged from 28.6% to 75% for acclimated fish and from 35.3% to 54.5% for direct release fish.

16. The weighted average homing rate was greater for 1+ fall chinook salmon (62.8%) than Ot fish (42.5%) or fall-release Ott fish (56.4%), based on an assortment of brood years from 1984 to 1991.

17. Time of entry into the Umatilla River for coho salmon is similar to that for fall chinook salmon and is dependent on a trigger flow of near 150 cfs. Weighted average homing and straying (to Cascade Hatchery) rates during the 1988 - 1992 return years were 85.4% and 14.6%, respectively.

18. Weighted average homing rates have been similar for acclimated (70.4%) and direct release (72.1%) coho salmon.

19. The flow trigger for major entry of summer steelhead into the Umatilla River ranges between 500 cfs and 1,000 cfs. Temperatures < 40 F delay entry. Summer steelhead enter into the Umatilla River from November through April.

20. Spring chinook salmon migration into the Umatilla River begins in early April and generally peaks in mid-May; entry does not appear to require a flow trigger.

21. Stray rates for Umatilla River spring chinook salmon have remained low (5.2% to 0%). Some of those that entered the Umatilla River had previously migrated up to or over McNary Dam.

REPORT A

Evaluation of Feed and Furnish canal bypass facilities, of juvenile salmonid passage through fish ladders, and of trap and load procedures at Westland Canal on the Umatilla River

Prepared by:
William A. Cameron
Boyd P. Schrank
Suzanne M. Knapp

Oregon Department of Fish and Wildlife

CONTENTS

CONTENTS (continued)

CONTENTS (continued)

ABSTRACT

We report on our efforts from October 1993 through September 1994 to evaluate the Feed and Furnish Canal juvenile **salmonid** bypass facilities on the Umatilla River in northeastern Oregon. Passage success was evaluated by injury and screen leakage tests and estimates of travel time through facility components. We also report on efforts to (1) evaluate **smolt** injury incurred during passage through the Feed Canal, Stanfield, Westland, and Three Mile Falls Dam fish ladders, and injury associated with smolt transport loading procedures at **Westland** Canal; (2) measure water velocities at screens and bypass channels at all diversion facilities; and (3) routinely monitor facilities for juvenile **salmonid** passage problems.

Yearling spring chinook salmon passing through the entire screening facility at Feed Canal and trapped at the bypass outlet received statistically significant injury, although the magnitude of this injury was not large. Trapping and handling effects and low recapture (27%) possibly confounded the injury results. Fish received low, but statistically non-significant injury as they quickly passed through the adult fish ladder at Feed Canal Dam. Total screening efficiency of the rotary drum screens was **99.95%,** even though fish leakage occurred at seven of the 10 screens. Mean fork length of fish that leaked was 63 mm. Using an improved technique and a new meter, approach velocities measured at the drum screens exceeded criteria for **salmonid** fry (I 0.4 fps) at about half the sampling locations, but met criteria for fingerlings **(≤** 0.8 fps) at most locations. Sweep velocities ranged from near 1 fps to 2 fps at all screens except Screen 1, where velocities were very low. Overall, approach velocities were fairly uniform among depths and screens, but sweep velocities were not. Mean velocity in the bypass channel was 2.24 fps.

At Furnish Canal, fall chinook salmon incurred statistically non-significant injuries through the headworks canal, screening facility, bypass pipe, and adult fish **ladder.** Fifty percent of the test fish traveled from the headgates to the bypass channel (0.6 miles) in two hours, from above the drum screens to the bypass channel in half-an-hour, from the bypass channel to the bypass outlet in one-third hour, and through the fish ladder in 12 minutes. Facility drum screens were 99.99% efficient in preventing fish leakage into the canal. The one leaked fish was 60 mm. Drum screen approach velocities met criteria for **salmonid** fry at 56% of the sampling locations and at all locations for **salmonid** fingerlings. Mean approach velocity and estimated flow were highest at Screens 3, 4, and 7. Sweep velocities ranged from 0.97 fps to 1.65 fps, increasing with proximity to the bypass channel, where velocity was a uniform 2.65 fps.

Juvenile fall chinook salmon incurred statistically significant injury and passed slowly (0.36 hours) through the auxiliary water side of the **Westland** Dam adult fish ladder; travel through the passage side was non-injurious and quick (0.12 hours). Juvenile **salmonid** loading procedures at the **Westland** Canal trap site, using either a fish pump or fish lift pescalator, caused few injuries to subyearling chinook salmon. However, loading efficiency and conditions for fish are poor with pescalator use. Drum screen approach velocities met criteria for **salmonid** fry and fingerlings at most or all sampling locations and were fairly uniform among depths and screens. Sweep velocities ranged from 0.79 fps to 1.66 fps and were highest at middle Screens 4 - 8. Mean velocity at the bypass channel was uniformly 2.10 fps.

As in 1993, tests of smolt injury at the east-bank ladder at Three Mile Falls Dam were confounded by low recapture rates and trap-caused injury. As such, our data suggested no statistically significant injury to yearling spring chinook salmon passing through ladder diffusers, vertical slots, or over the auxiliary water weir, although scale loss did occur. Modification to a fish exit gate since our 1993 tests may have alleviated some of the injury potential. Water velocities directly upstream of the modified lead diffuser (gate) ranged from 0.44 fps to 2.03 fps (mean = 1.01 fps), with highest velocities occurring near the water surface and gate sides.. Velocities collected in one location at a l-foot depth upstream of the auxiliary water diffuser averaged 0.54 fps. We tested an underwater video camera system for monitoring smolt passage at the fish exit gate, and determined its drawbacks and capabilities. When the bypass was closed, drum screen approach velocities at the West Extension Canal were fairly uniform among screens (0.11 fps to 0.14 fps) and met criteria for both salmonid fry and fingerlings. Mean sweep velocities were highest at Screen 1 (0.71 fps) and lowest at Screen 4 (0.51 fps), but fairly uniform among depths (0.60 fps to 0.68 fps).

At Maxwell Canal, approach velocity criteria for salmonid fry and fingerlings were met at 85% and 100% of the sampling locations, respectively. Uniformity in approach velocity was slightly better among screens than among sampling depths. Mean sweep velocity at the three screens ranged from 0.41 fps to 1.01 fps, increasing with screen proximity to the bypass channel.

Year-round surveys at the ladder and bypass facilities detected some passage problems, although overall operation and maintenance was fairly adequate. During high flows, acute problems arose with debris blockage at the modified fish exit gate at Three Mile Falls Dam and chronic debris occlusion problems occurred at most sites. Silt deposition in front of the drum screens at Feed Canal was extensive. During midwinter low flows, passage conditions were very poor for upstream and downstream migrants at Westland Dam. Gravel and debris blockages at the fish exit and auxiliary water intake unfavorably altered hydraulics at the ladder. Although the modified bypass pipe at Westland Canal worked well in effectively returning fish to the river, a problem continues with smolt escape at the fish separator at the Westland trapping facility. Various sites were void of staff gauges for measuring water depths and head differentials. Fine-tuning of operations, operating criteria, and structures is needed at some facilities to improve passage conditions.

We make suggestions to improve juvenile passage at adult fish ladders, enhance screening efficiency and sealing effectiveness at bypass facilities, develop pertinent operating criteria, and install measuring devices. Turbulent flow through the fish ladder at Feed Canal Dam and a mid-channel I-beam upstream of the fish exit at Three Mile Falls Dam create unfavorable passage conditions for juvenile fish. Retrofitting drums screens with foot and top wedges and improving the design for bottom seal mounts would create a tighter seal and reduce entrainment. Drum screen side bands could potentially reduce side seal wear. Improved regulation of canal flows could be achieved with regular and proper use of automated headgates. More strategically located staff gauges within the screening and ladder facilities would assist in the fine-tuning of flows. We recommend the fish pump for loading juvenile fish at Westland Canal, rather than the use of dip nets or the pescalator.

INTRODUCTION

Large runs of salmon *(Oncorhyncus spp.)* and steelhead (0. *mykiss*) once supported productive fisheries in the Umatilla River. By the 1920s, stream impoundments with inadequate passage facilities and habitat degradation had extirpated the salmon run and drastically reduced the steelhead run (ODFW and CTUIR 1989a). However, a comprehensive fisheries rehabilitation program was initiated in the mid-1980s thatimproved passage facilities, fish habitat, hatchery production, and river flow (Boyce 1986). Improvements in salmon runs in the Umatilla River are presently sufficient to provide a fishery, but still well below long-range management goals (ODFW and CTUIR 1989b).

The Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program (1987) provided the impetus for fisheries rehabilitation projects throughout the Columbia Basin (Section 1403, Measure 4.2). Reconstruction of outdated and ineffective passage facilities on the Umatilla River was a cooperative effort among the Bonneville Power Administration (BPA), Confederated Tribes of the Umatilla Indian Reservation (CTUIR), various fish and wildlife agencies, and the U.S. Bureau of Reclamation (USBR). These improvements included reconstructed and new fish ladders, state-of-the-art bypass facilities, newly designed canal screens, and at some locations, fish trapping and holding facilities.

Evaluation of passage facilities at irrigation diversions on the Umatilla River was recommended in *A Comprehensive Plan for Rehabilitation of Anadromous Fish Stocks in the Umatilla River Basin* (Boyce 1986). We are presently evaluating juvenile fish passage at major irrigation diversions while CTUIR, under subcontract to Oregon Department Fish and Wildlife (ODFW), is evaluating adult fish passage at and between these diversions. Evaluations of similar fish screening facilities on the Yakima River, Washington, were used as a general model for the juvenile passage study design (Neitzel et al. 1985, 1987, 1988, 1990a, 1990b; and Hosey and Associates 1988a, 1988b, 1989, 1990).

We operated the West Extension Irrigation District (WEID) Canal fish bypass facility in 1989 to test fish sampling equipment. In 1990, 1991, and 1992 we collected data on river-run fish and conducted fish injury and leakage tests at the West Extension Canal (Knapp and Ward 1990, Hayes et al. 1992, Cameron and Knapp 1993). Tests of injury and leakage showed that juvenile salmonids were not injured during passage through the bypass facility and that screening efficiency of the drum screens approached 100%. Impingement of fry and subyearling fish on the traveling screen was the most serious problem observed. We found that fish moved freely through the upper screening facility, but were delayed in the outfall at a bypass flow of 5 cfs. Findings from our evaluation studies have resulted in structural and operational improvements to the facility.

In 1992, we also compared juvenile salmonid passage rates through the West Extension Canal fish bypass facility with passage rates through the east-bank adult fish ladder on the opposite side of Three Mile Falls Dam. Downstream passage rates of juvenile salmonids at the fish ladder were roughly equal to passage rates at the fish bypass facility (Cameron and Knapp 1993). This finding prompted us to broaden the scope of our study to include evaluation of injury to juvenile salmonids incurred during passage through fish ladders.

In 1993, fourth year study efforts were focused primarily at Westland Canal (Cameron et al. 1994). Facility-caused injury to spring and fall chinook salmon was low in all tests, but fish injury occurred during dipnetting and crowding when they were being loaded for transport to the lower river. Chinook salmon moved through the upper facility between 0.2 hours to 16 hours. Drum screens were near or at 100% efficiency, with leakage occurring mostly through the end screens. Drum screen velocities were not uniform among screens, but generally within criteria. Bypass channel velocity was high (4 fps) under revised criteria requiring a fully lowered bypass weir.

Secondary studies in 1993 were conducted at Feed, Maxwell, and West Extension canals and the east-bank adult fish ladder at Three Mile Falls Dam (Cameron et al. 1994). Juvenile fall chinook salmon were injured primarily as they passed through the passage portion of the ladder at Three Mile Falls Dam rather than through the auxiliary water portion. Operating both canal pumps at the West Extension Canal. or opening the river-return drain pipe 40%, produced hydraulic conditions conducive to fry impingement. Fish traveled through the 1.5-mile headworks canal at Maxwell Dam within 3 hours (median travel time) and without injury. Approach and sweep velocities at Feed Canal drum screens were excessive when screens were less than 80% submerged.

Our approach to defining study objectives for 1994 involved, in part, an identification of past results that were inconclusive or incomplete. Injury to smolts passing through the east-bank ladder at Three Mile Falls Dam prompted a modification of the ladder fish exit gate to reduce injury potential. However, additional information was needed on the extent of injury before major operational or structural changes would be made. Juvenile transport procedures evaluated in 1993 at Westland Canal were limited to the crowding and dipnetting processes. Two other procedures for fish loading included the use of a fish pump and a "fish lift" (pescalator). These procedures required testing to determine their impact on fish condition during loading. In addition, results from velocity measurements in 1993 caused concern as to their validity. Our use of an older model electromagnetic velocity meter and a technique that could have resulted in inaccurate readings prompted us to explore alternative techniques and improvements in equipment. A repeat of velocity measurements at all facilities using an improved meter and methods was considered prudent and necessary. Finally, since efforts were unsuccessful last year to evaluate injury to smolts passing through the Westland Dam fish ladder, we re-attempted this test in 1994.

New tasks for 1994 were a result of our need to fully complete the juvenile passage evaluation project during this year. Past experience had shown that changing river and facility conditions throughout the year influenced successful fish passage. We knew that bypass facility evaluations conducted at one point in time did not necessarily identify passage problems occurring at other times of the year under different conditions or operations. We considered documentation of passage problems that occur during various canal, ladder, or facility operations, river flows, and migration periods to be an important part of a passage evaluation. Lastly, two remaining diversions, and their associated passage facilities, required comprehensive evaluations.

In this report we describe progress toward our fifth and final year study objectives. Most of our effort was focused at Feed Canal and Stanfield diversions, and their respective bypass and ladder facilities. We estimated drum screen efficiencies and rates of injury to, and travel time of, juvenile salmonids as they passed through these facilities. We measured water velocities at all screening facilities, investigated injury potential to juvenile fish with pump and pescalator-loading at Westland Canal, estimated injury to juvenile salmonids passing through fish ladders at Westland and Three Mile Falls dams, and periodically surveyed all facilities for passage problems. We also describe exploratory work with an underwater video camera to document smolt passage problems at Three Mile Falls Dam.

STUDY SITES

Five major diversion dams on the lower Umatilla River, owned and maintained by the U.S. Bureau of Reclamation and operated by one of three irrigation districts, were the focus of our evaluation efforts (Figure 1). State-of-the-art adult and juvenile salmonid passage facilities were constructed at these dams and their associated canals between 1988 and 1993, as called for in the Northwest Power Planning Council's Fish and Wildlife Program (NPPC 1987). All juvenile fish bypass facilities share common structural and operational features. However, the need to meet site-specific differences in facility function, canal capacity, topography, and river channel characteristics resulted in a unique design for each facility. All juvenile fish bypass and adult fish passage facilities operate in accordance with both general and site-specific standard operating criteria developed by the National Marine Fisheries Service (APPENDIX A).

In 1994, we conducted indepth evaluations of fish passage facilities at Feed Canal Dam (Figure 2) and Stanfield Dam (Figure 3); short-term investigations were conducted at passage facilities at Westland, Maxwell, and Three Mile Falls dams. Design of the juvenile fish bypass facility at the West Extension Irrigation District Canal, located on the west bank of Three Mile Falls Dam, has been previously described (Knapp and Ward 1990, Knapp 1992, Cameron and Knapp 1993). Descriptions of the adult fish passage facility at Three Mile Falls Dam and juvenile fish bypass facilities at Westland and Maxwell canals are included in Cameron et al. (1994). The bypass pipe at Westland Canal has since been shortened and modified to allow a safe, more effective fish return to the river.

Features common to all screening sites include (1) canal headgates and checkgates and a bypass channel weir for regulating canal withdrawals, headworks water elevation, and bypass flow, respectively; (2) rotary drum screens and a bypass channel, downwell, pipe, and outfall to screen fish from the canal and return them to the river; and (3) a trash rack to intercept debris prior to entering the facility.

Feed Canal (Figure 2), located at Feed Canal Dam, delivers irrigation storage water to Cold Springs Reservoir (Figure 1). Feed Canal is supplied by water passing through eight headgates adjacent to the north side of Feed Canal Dam. Distance from the headgates to the juvenile fish bypass channel is approximately 675 feet. This facility will pass a maximum nominal flow of 245 cfs through 10 rotary drum screens and 18 cfs through the bypass channel.

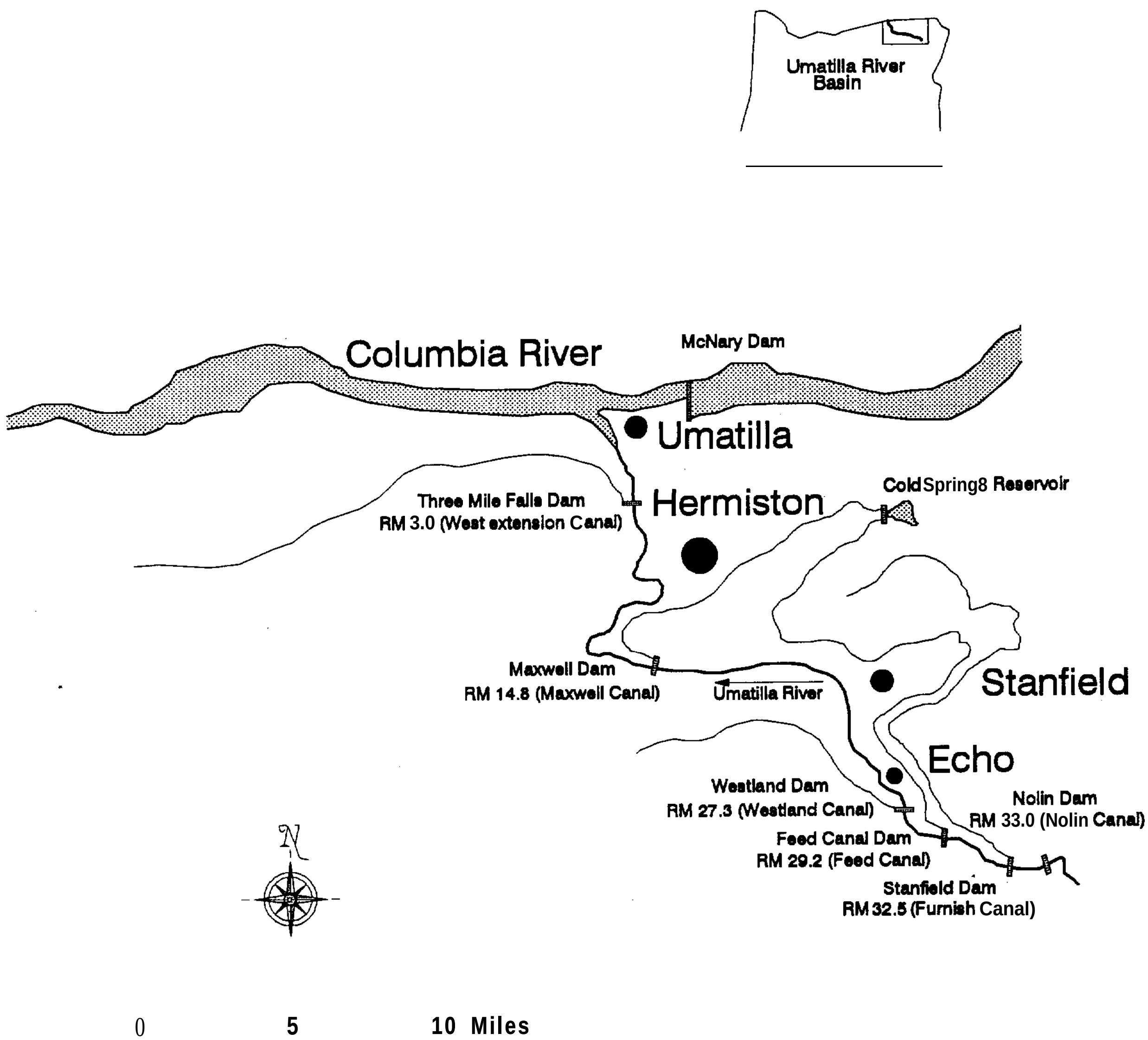
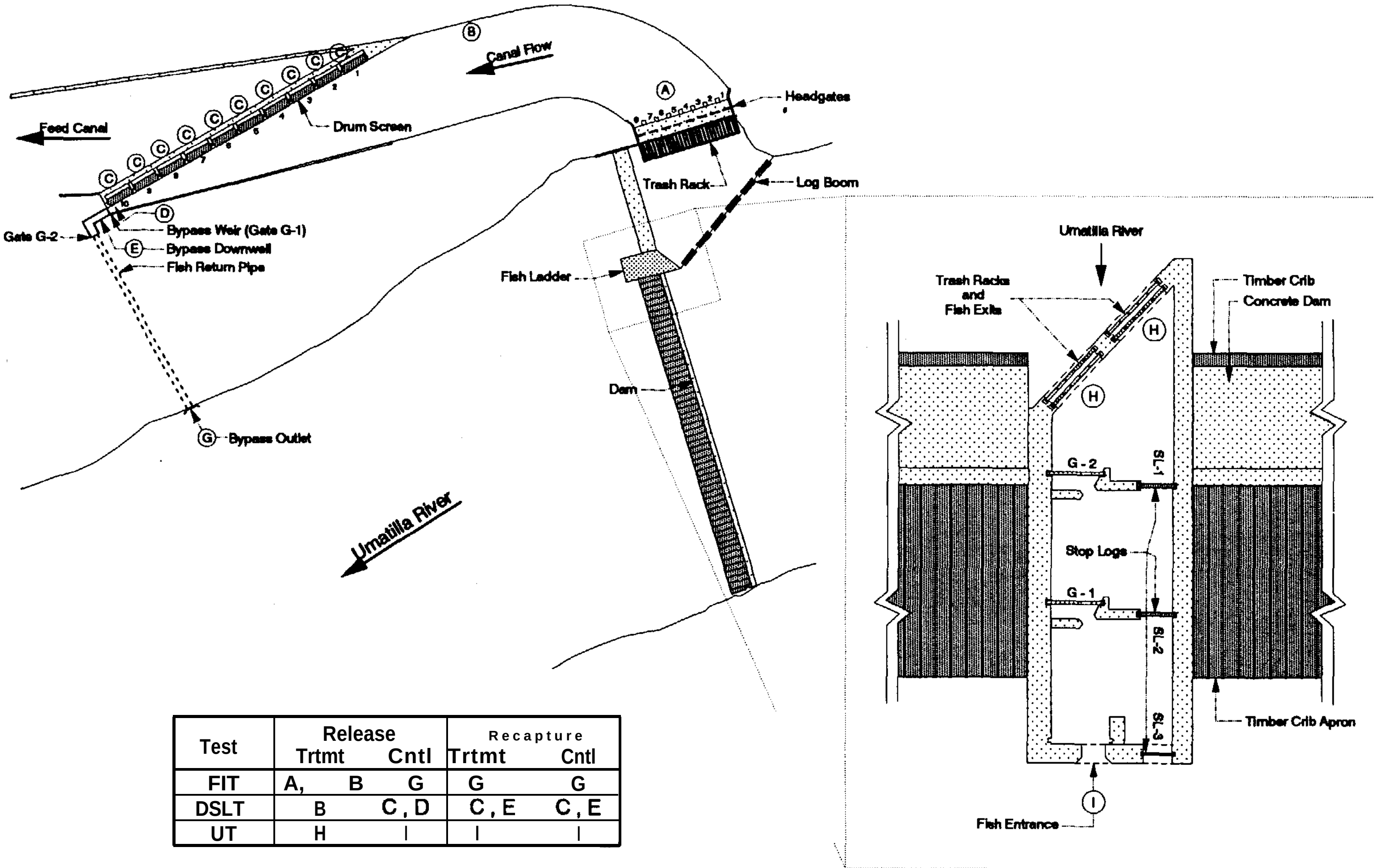
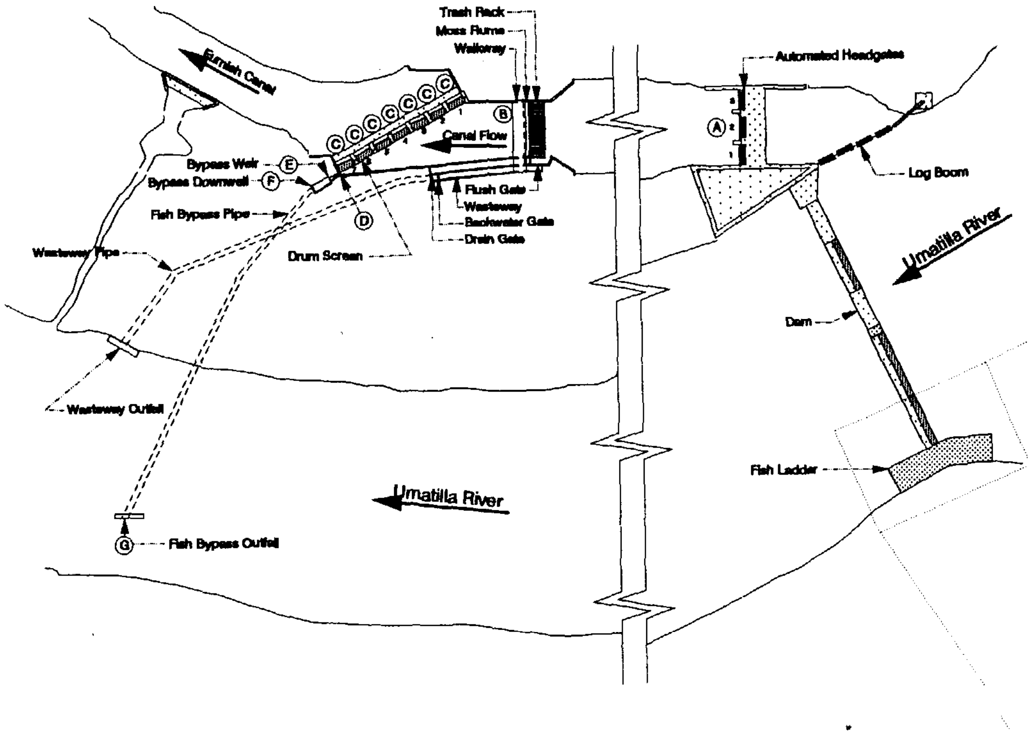


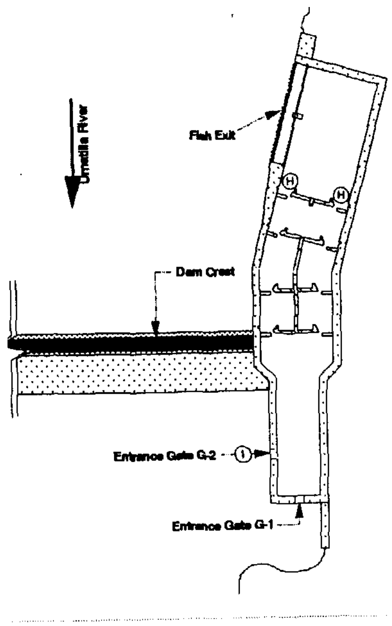
Figure 1. Locations of diversion dams and canals on the lower Umatilla River, Oregon.



Test	Release		Recapture	
	Trtmt	Cntl	Trtmt	Cntl
FIT	A, B	G	G	G
DSLT	B	C, D	C, E	C, E
UT	H	I	I	I

Figure 2. Schematic of Feed Canal juvenile fish bypass facility and the Feed Canal Dam adult fish ladder, Umatilla River, including locations for release and recapture of test fish. Not drawn to scale.





Test	Release Trtmt	Release Cntl	Recapture Trtmt	Recapture Cntl
CIT	A	B	F	F
SIT	B	E	F	F
BOIT	E	G	G	G
DSLT	B	C, D	C, F	C, F
LIT	H	I	I	I

Figure 3. Schematic of the Furnish Canal juvenile fish bypass facility and the Stanfield Dam adult fish ladder, Umatilla River, including locations for release and recapture of test fish. Not drawn to scale.

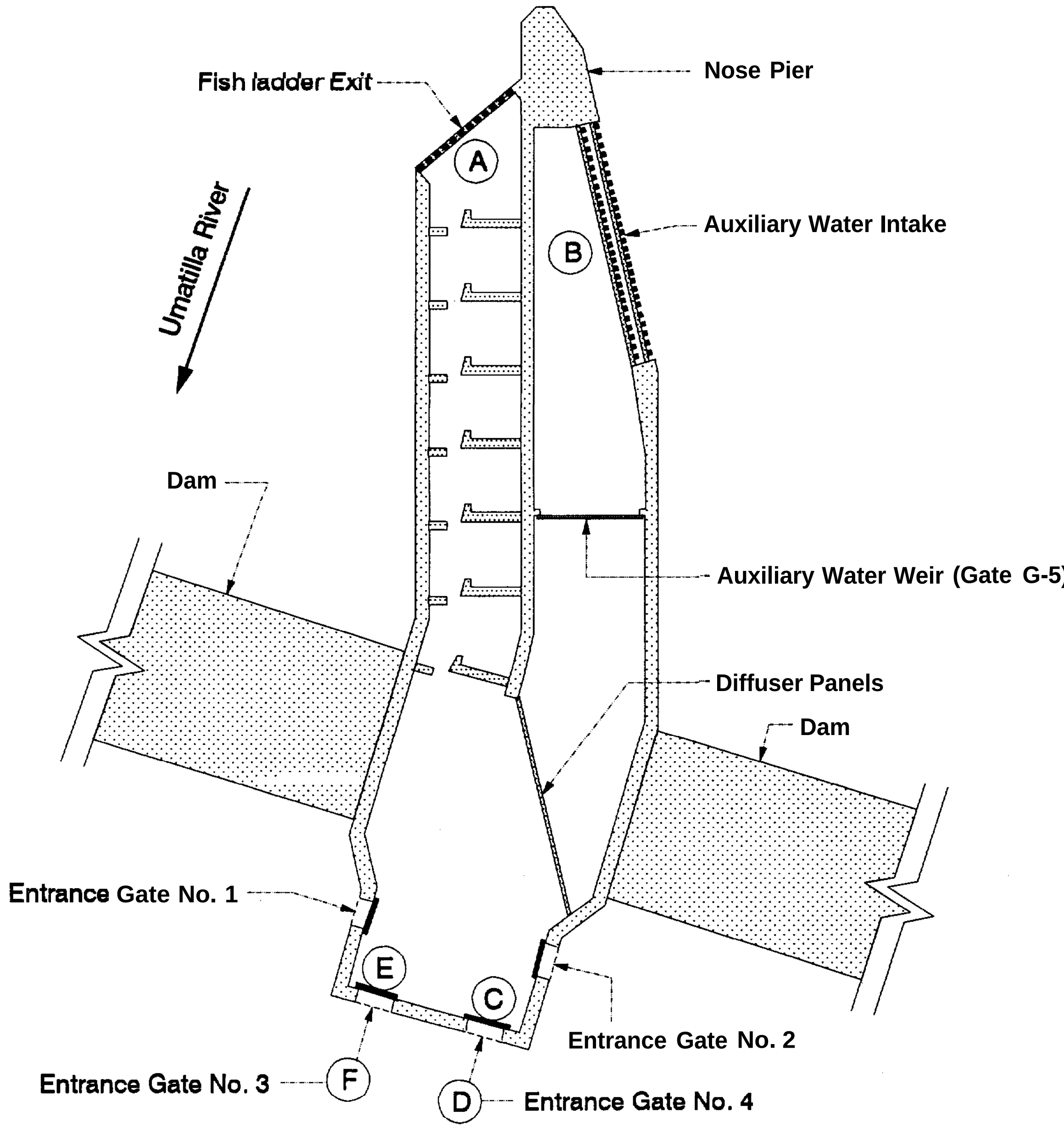
Bypass flow is reduced from 18 cfs to 5.5 cfs when river flow no longer spills over the dam. Baffle boards located in slots behind the drum screens occlude 50% of the water column to force water at higher velocities through a 6-inch bottom gap to prevent excess silt deposition. An underground, 30-inch-diameter, 300-foot-long bypass pipe returns fish from the bypass downwell to the river at a partially submerged outlet structure located on the river bank. Canal operation generally extends from mid-November to mid-May.

Furnish Canal (Figure 3) is supplied by water passing through three headgates adjacent to the north side of Stanfield Dam. The canal delivers irrigation water to locations east of the Umatilla River between Echo and Hermiston (Figure 1). Distance from the headgates to the juvenile fish bypass channel is approximately 0.6 miles. Depending on river flow, this facility will pass a maximum nominal flow of 150 cfs through seven rotary drum screens, and from 15 cfs to 20 cfs through the bypass channel. Screen foot and top wedges on the back side of the screen force it tight against the screen guides to minimize gaps and the potential for fish leakage. Baffle boards behind all drum screens prevent excess silt deposition, as at Feed Canal. An underground, 24-inch-diameter, 460-foot-long bypass pipe returns fish from the bypass downwell to the river at a submerged outlet structure located in the main river channel. A wasteway channel located in the screen forebay is used to dampen fluctuations in water surface height during adjustments to canal headgates and checkgates. Canal operation generally extends from mid-March to mid-October.

Fish trapping facilities for sampling or collecting juvenile fish are located at the juvenile fish bypasses at Westland and West Extension canals. A pescalator (fish lift) or Neilson fish pump are used to load fish from the holding pond to transport vehicles at the Westland Canal trapping facility. The pescalator is a 20-inch-diameter, 28.5-foot-long, inclined fiberglass auger tube with a S-foot-diameter entry brailer. Powered by a 1.5-hp motor, the tube rotates, scooping water and fish into the brailer and tube. Continued rotation spirals the contents upward to a top dewatering chute; as water is eliminated, fish slide forward and drop through a flex hose into the transport vehicle. The Neilson fish pump pulls water and fish from the holding pond through an 8-inch-diameter flex hose attached to an impeller housing. A gasoline engine rotates the impeller, propelling water and fish up a vertical segment of flex hose and down a dewatering chute into a transport vehicle.

Facilities for adult fish passage at the various diversions differ with respect to inriver location, operation, and structural design. Fish ladders at Westland (Figure 4) and Three Mile Falls (Figure 5) diversions incorporate passage and auxiliary water sections to the total ladder structure. The passage portion provides a route for adult fish migration, whereas the auxiliary water portion increases flow through the fish entrance to help fish locate the ladder. Ladders at Feed Canal Dam (Figure 2) and Stanfield Dam (Figure 3) do not provide auxiliary flow and are considered "low flow" passage ladders.

The fish ladder at Feed Canal Dam is approximately 35 feet long and located on the north side of the river channel near the canal headgates (Figure 2). Positioning of two ladder orifice gates (G-l and G-2) maintains proper flow conditions within the ladder with increases and decreases in river



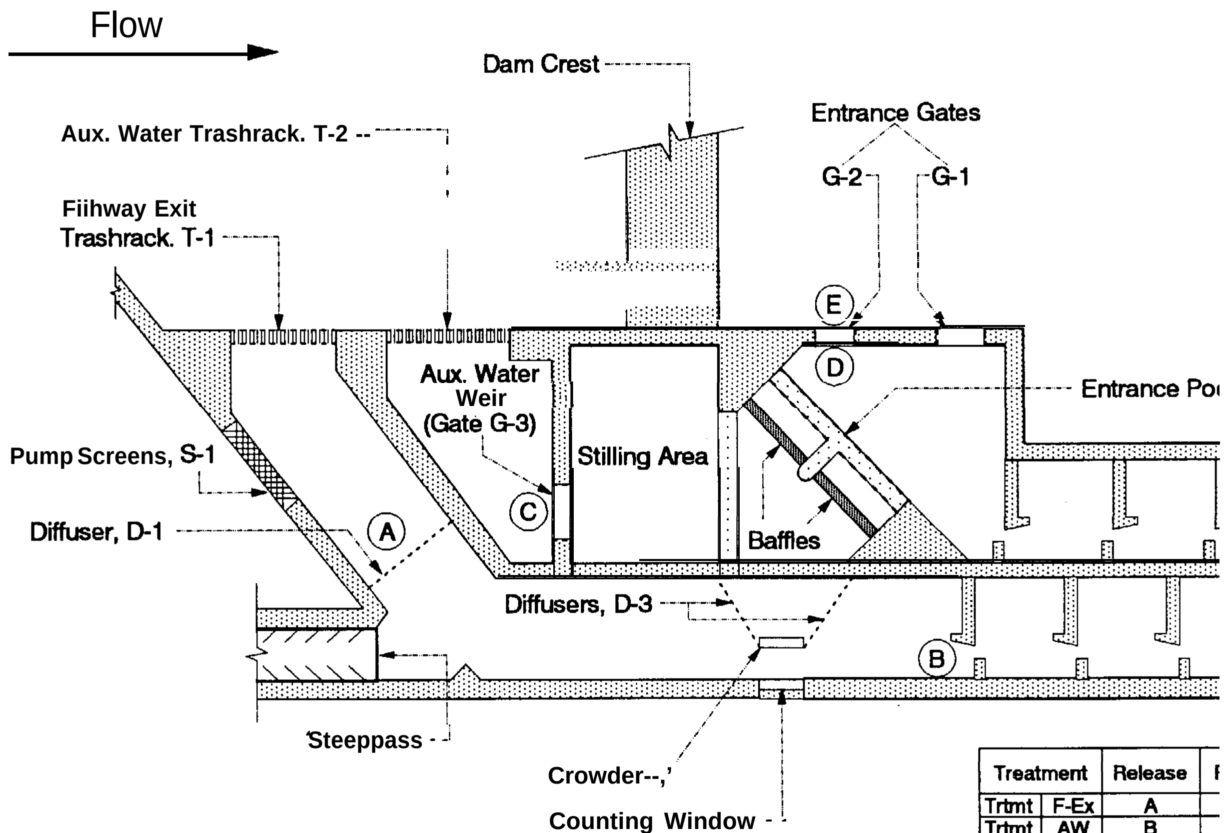
Summer steelhead

Treatment		Release	Recapture
Trtmt	F-Ex	A	D
Trtmt	AW	B	D
Cntl	F-En	C	D

Subyearling fall chinook salmon

Treatment		Release	Recapture
Trtmt	F-Ex	A	D , F
Trtmt	AW	B	D , F
Cntl	F-En	C , E	D , F

Figure 4. Schematic of the adult fish passage facility at Westland Dam, Umatilla River, including locations for release and recapture of test fish.



Treatment		Release	F
Trtmt	F-Ex	A	
Trtmt	AW	B	
Cntl	F-En	C	
Cntl		D	

Figure 5. Schematic of the east-bank adult fish passage facility at Three Mile Fa
including locations for release and recapture of test fish.

flow. Stoplogs (SL-1, SL-2, SL-3) in guides within the ladder are temporarily removed to sluice silt deposited inside the structure (APPENDIX A).

The fish ladder at Stanfield Dam is located on the opposite bank of the river (south) as the canal headgates and measures approximately 90 feet long (Figure 3). An open or closed configuration of two entrance gates (high flow and low flow) maintains proper conditions for fish passage between the ladder entrance pool and dam tailwater. Due to the formation of a gravel bar in front of the high flow entrance gate (G-2), this gate is not operated for fish passage. The low flow entrance gate (G-l) is currently used to pass fish under existing flow conditions. Adjacent dam boards raise (boards installed) or lower (boards removed) the river elevation above the dam to facilitate diversion (APPENDIX A). When dam boards are used, adjustments to ladder operation are necessary.

The fish ladder at Westland Dam measures approximately 100 feet long, is located midchannel, and functions in one of several standard operating modes (Figure 4; APPENDIX A). The specific mode used is dictated by the dam tailwater level outside the entrance gates. Proper ladder conditions for fish passage are maintained with an open or closed configuration of four entrance gates and the throttling of an auxiliary water weir gate. A head differential from ladder entrance to dam tailwater is maintained at 0.5 feet to 1.0 feet. Depending on river flow, one or two of the entrance gates may be open at any one time. As at Stanfield Dam, the use of dam boards requires adjustments in ladder operation.

The east-bank fish ladder at Three Mile Falls Dam measures approximately 150 feet long from exit to entrance. The ladder turns 180 degrees approximately midpoint between the entrance gates and fishway exit (Figure 5). This facility operates with only one of two fish entrance gates (high flow or low flow) open. The low flow fish entrance gate (G-l; Figure 5) is open when river flow past the dam is less than 1,600 cfs (APPENDIX A). Head differential from ladder entrance pool to dam tailwater is maintained at 1.0 feet to 1.5 feet.

To monitor river flow and canal withdrawals within the Umatilla River Basin, automated monitoring and recording stations were installed at various river and canal locations by the U.S. Bureau of Reclamation. We used flow data from this hydrological-meteorological (HYDROMET) data acquisition system to verify our velocity measurements and for general flow information. Flow data from each station is transferred to the HYDROMET computer data base in Yakima, Washington, via satellite. We used data recorded from stations located at Feed (FCEO), Furnish (FURO), Westland (WESO), and Maxwell (MAXO).

METHODS

Feed Canal Dam and Feed Canal

Injury

Injury tests consisted of release and recapture of three replicate groups of marked treatment and control fish on two or three separate dates (Appendix Table B-l). Treatment fish were released upstream of the facility structure being evaluated; control fish were released either immediately downstream from the structure or in a recovery trap to assess collection efficiency and trap-caused injury (Figure 2). We used a floating fyke net trap at the bypass outlet and fish ladder entrance to recapture test fish (Cameron et al. 1994). At the bypass outlet, we removed the trap floats and attached the net mouth to the outlet structure.

Test fish used in facility evaluations were held 3 to 9 days in 800-gallon circular tanks prior to marking (Knapp 1992). Each treatment and control group consisted of approximately 100 fish that were given one unique mark on their ventral body surface prior to release. We injected fish with approximately 0.1 ml of acrylic paint using a 3 cc disposable syringe equipped with a 26-gauge intradermal needle. Several paint colors and body locations were used throughout the study to achieve the necessary number of unique marks. We conducted a seven-day mark retention test with yearling spring chinook salmon to verify that the syringe marks had adequate longevity for use in short duration tests (Appendix Table C-l). All fish were evaluated for pre-test injury during the marking procedure, then placed in 20-gallon holding containers to recover (Knapp 1992). Due to the large size of test fish (8 fish per pound), we divided each release group equally between two holding containers. Test fish were allowed two to four hours for recovery prior to test release. We handled all fish in the same manner to reduce handling bias.

We assessed fish condition to estimate injury. Fish condition was determined using a modified version of the descaling criteria developed by the U.S. Army Corps of Engineers (Neitzel et al. 1985). We modified the descaling criteria by subdividing the partially descaled injury category (> 3% and < 40% scale loss) into low (> 3% and ≤ 20% scale loss) and moderate (> 20% and <40% scale loss) partial descaling. Fish injured, but not incurring scale loss, were designated as "otherwise injured."

Facility-caused injury was evaluated by comparing condition (injury rates) of treatment and control fish after recapture. Pre-test injury rates were subtracted from post-test injury rates to standardize initial injury rates for each release group. Pre-test injury rates and post-test injury rates were calculated for each release group as the percentage of uninjured, low partly descaled, moderate partly descaled, otherwise injured, descaled, and dead fish. We multiplied (weighted) the percentages of injury types by numerical factors to provide a qualitative measure of fish condition: uninjured (O.O), low partly descaled (0.167), moderate partly descaled (0.33), otherwise injured (0.33), descaled (0.67), and'dead (1.0). Weighted injury was then calculated for each pre-test and post-test group as the sum of the weighted injuries for all injury categories. Net weighted injury was calculated by subtracting weighted injury of pre-test from the weighted injury of their corresponding post-test group.

Paired T-tests were used to determine whether mean, net weighted injury for treatment minus control was significantly greater than zero. We based our pairing of replicate treatment and control groups by common release times. We chose as our significance level (a) a P value of ≤ 0.10 using a one-tailed test of significance. Statistically significant results and results that were "near significance" were highlighted in the report. We computed a 90% confidence interval about the mean difference between treatment and control net weighted injury rates. The assumption of normality was tested prior to conducting parametric statistical analysis. Non-parametric statistical analysis was also conducted if data did not meet the normality assumption. All testing was completed using the SAS program for personal computers (SAS Institute Inc. 1990).

We evaluated injury to yearling spring chinook salmon associated with passage through the juvenile fish bypass facility and adult fish ladder at Feed Canal Dam. Fish from Umatilla Hatchery, designated for release in the Umatilla River, were used in the tests in March 1994 (Appendix Table B-2). Operating criteria for the fish bypass and ladder facilities have been developed by the National Marine Fisheries Service (APPENDIX A). During tests, the bypass operated according to normal operation criteria with a bypass flow of 18 cfs; the fish ladder operated according to normal streamflow criteria (APPENDIX A). Canal withdrawals (preliminary data) were near maximum nominal flow, ranging from 215 cfs to 242 cfs. We monitored water temperature in the canal headworks at a depth of 0.5 meters using a Taylor maximum-minimum thermometer.

For the facility injury test (FIT), we evaluated injury to spring chinook salmon that traveled from the headgates past the drum screens and through the bypass downwell, pipe, and outlet. All headgates were approximately 40% open, except Headgates 4 and 8 (closed), when tests were conducted from 23 March to 25 March 1994 (Appendix Table B-3). On the first day of testing, we released treatment fish immediately downstream of Headgate 4 (Figure 2). Throughout the remainder of the test, we released treatment fish 150 feet upstream of the drum screens to improve recapture rates. Control fish were released into the mouth of the fyke net at the bypass outlet using a dip net. For each release group, both containers of fish were released within five minutes of each other.

For the ladder injury test (LIT), we evaluated injury to spring chinook salmon that traveled from the fish exit, through the ladder, and out the fish entrance. We released treatment fish immediately downstream of the fish exit and released control fish into the mouth of the fyke net using a dip net (Figure 2). For each release group, both containers of fish were released within 10 minutes of each other.

Recovery and Travel Time

Recovery and travel time analysis was only conducted on data collected from the second and third day of testing due to the change in release location. We recorded release and recapture times during injury tests to determine the average time for test fish to travel from the release point to the recovery point (travel time). Travel distance from release to recapture was 225 feet. We estimated travel time by calculating the time to recapture 50% (median travel time) and 95% (95% travel time) of the test fish released. Percent recovery was based on the proportion of fish recovered by the end of the test.

Drum Screen Efficiency

We monitored passage of juvenile salmonids through (leakage) or over (impingement and roll-over) the drum screens at Feed Canal from 5 April to 10 April using fingerling fall chinook salmon obtained from Umatilla Hatchery (Appendix Table B-Z). (Wire tagging of all fall chinook salmon from this hatchery delayed our acquisition of them until after the fry stage.) The facility operated according to normal operation criteria with a bypass flow of 18 cfs during the test (APPENDIX A). Canal withdrawals (preliminary data) were near maximum nominal flow and ranged from 208 cfs to 215 cfs during the test.

We placed fyke nets (Cameron et al. 1994) on the downstream side of each drum screen and released test fish in the screen forebay (treatment) to document fish leakage. Mean size of test fish released upstream of the screens was 64.1 mm (Appendix Table C-2). Two releases of test fish were made every other day (Appendix Table B-l). On each release date, we released approximately 500 treatment fish upstream of the screens and 250 control fish at the bypass channel entrance in the midmorning and midafternoon; we released 100 control fish downstream of each drum screen in the midmorning to estimate fyke net efficiency (Figure 2). Control fish were differentially stained with Bismark-brown dye prior to release. We checked the fyke nets at approximately 12-hour intervals.

Individual drum screen efficiencies were calculated as the ratio of the number of treatment fish recaptured behind each drum screen to the number of fish that were guided past the screens. Separate drum screen efficiencies were calculated for all three test periods, then averaged to estimate mean screen efficiencies per screen. Overall efficiency of the drum screens was derived from the ratio of leakage summed over all screens and dates to the total number of fish that were guided past the screens on all dates. Drum screen efficiency estimates were corrected for fyke-net capture efficiency (EFFfn) and bypass collection efficiency (EFF_{bc}). We assumed fish caught were retained; thus, no adjustment for retention was applied to net capture efficiency.

The formula for calculating fyke-net capture efficiency (EFFfn) behind each drum screen was

$$EFFfn = \frac{n_{fn}}{N_{fn}}$$

where

n_{fn} = the number of control fish captured in the fyke net, and
Nfn = the number of control fish released at the fyke net mouth.

The formula for calculating bypass collection efficiency (EFF_{bc}) was

$$EFF_{bc} = \frac{nbc}{Nbc}$$

where

nbc = the number of control fish released at the bypass channel entrance and captured in the downwell trap, and
N_{bc} = the number of control fish released at the bypass channel entrance.

The formula for calculating percent drum screen efficiency (EFF_{ds}) was

$$EFF_{ds} = \left[1 - \frac{(Xfn)}{(EFF_{fn} \times N)} \right] (100)$$

where

X_{fn} = the number of treatment fish released upstream of the drum screens and recaptured behind the drum screen, and
N = an estimate of the total number of fish encountering the screens.

$$N = \frac{Xfn}{EFF_{fn}} + \frac{Xbc}{EFF_{bc}}$$

where

X_{bc} = the number of treatment fish released upstream of the drum screens and caught in the downwell trap.

Velocity and Flow Measurements

We collected velocity measurements at the Feed Canal drum screens to assess whether they met fish screening criteria developed by the National Marine Fisheries Service (NMFS 1989, 1990). Measurements were collected on 13 April and 14 April 1994 using a Marsh McBirney (Model 2000) electromagnetic flow meter. The facility operated according to normal operation criteria with a bypass flow of 18 cfs when measurements were collected (APPENDIX A). Canal flows were 210 cfs and 205 cfs (preliminary data; 84% to 86% of maximum nominal flow) on 13 April and 14 April, respectively. The meter was capable of providing two levels of velocity readings, fixed-point averages and instantaneous readings. For fixed-point averaging, the meter determined the mean of 30 velocity readings per second collected over a fixed period of time. For instantaneous readings, velocities were displayed instantaneously with output stabilizing over successive time intervals by the automatic removal of highest and lowest values. Maximum stabilization was reached after the fifth time interval. An interval of time for recording instantaneous readings (time constant) was set by the operator. Measurements were taken three to six inches upstream of the screens at three depths along transects located at 25%, 50%, and 75% of the screen length. Sampling depths at each transect were 20%, 50%, and 80% of screen submergence depth. Drum screen motors (220 volts) were operating during sampling. At each sampling location, we positioned the flow meter sensor probe parallel to the water surface and pointing into the vector of maximum velocity. We used a thin rod with flagging to determine the maximum velocity vector if water clarity was good. If water clarity was poor, we used as a gauge the maximum instantaneous velocity measured with a time constant setting of two seconds. To determine the angle of maximum velocity to the screen, we incorporated an angle measuring device onto the meter pole (Figure 6). To achieve proper alignment of the protractor, rods on the side of the protractor were positioned parallel to the screen length. The angle was then measured by rotating a cap and pin covering the protractor until the pin aligned with either the probe (good water clarity) or probe indicator line marked on the meter pole (poor water clarity).

We collected five water velocity measurements at each sampling location with the meter set for fixed point averaging over five-second intervals. We used trigonometric functions to calculate water velocity perpendicular (approach) and parallel (sweep) to the screens. Resultant approach and sweep velocities were calculated from the measured velocity and the measured angle converted to radians such that

$$\text{sweep velocity} = \text{COS}\left[\frac{\pi}{180}\,(\Theta)\;(V)\right]$$

and,

$$\text{approach velocity} = \text{SIN}\left[\frac{\pi}{180}\,(\Theta)\;(V)\right]$$

where

COS = Cosine function,
SIN = Sine function,
π = constant PI (3.14),
Θ = angle of maximum flow to screen face (in degrees), and
V = water velocity measured.

Multiple measurements collected at sampling locations and screen transect were averaged to determine mean sweep and approach velocities. We computed total flow through the screens from our velocity measurements to determine if our data corroborated with Bureau of Reclamation HYDROMET flow readings. Flow through each screen was calculated as the product of mean screen approach velocity (resultant), adjusted screen length, and submerged screen depth. Resultant velocities were used to assess adherence to criteria.

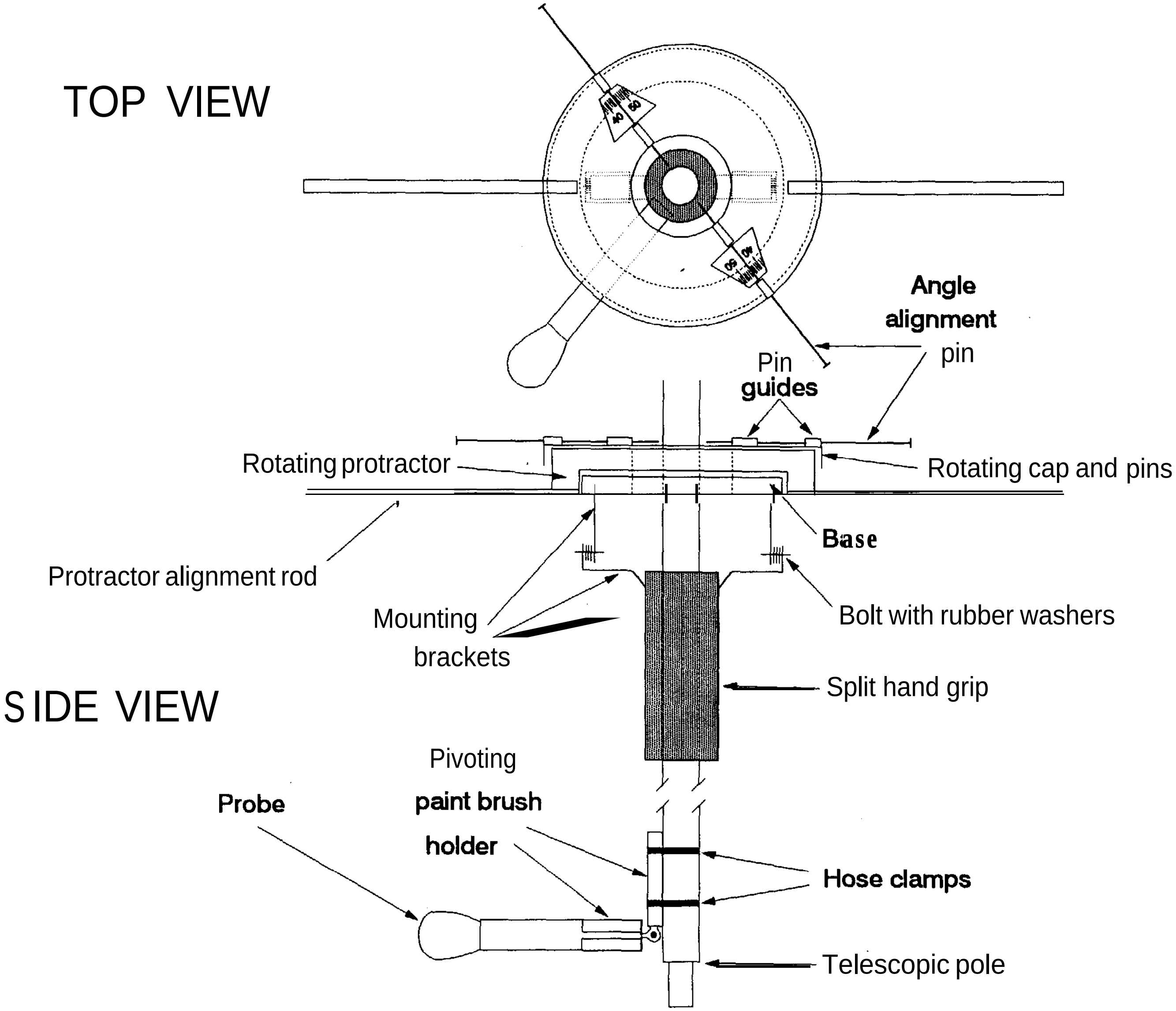


Figure 6. Device used in conjunction with an electromagnetic velocity meter to measure angle of maximum water velocity in front of screens and diffusers at fish'passage facilities on the Umatilla River, Oregon.

Stanfield Dam and Furnish Canal

Injury

We evaluated injury rates of subyearling fall chinook salmon associated with passage through the headworks canal, screen forebay, downwell, bypass pipe and outlet at Furnish Canal. During all tests, the fish bypass facility was operated according to normal streamflow operation criteria with a bypass flow of 20 cfs (APPENDIX A). Canal withdrawals were approximately 67% of maximum nominal flow, ranging from 79 cfs to 84 cfs (preliminary data) during the canal injury and screen injury tests. We followed the same methods for injury tests as described for Feed Canal, except that separate tests were conducted to evaluate the upper and lower bypass. Upper and lower bypass refer to portions of the fish bypass facility upstream and downstream of the bypass channel weir, respectively.

Tests evaluating injury caused by passage through the headworks canal (CIT) and screen facility (SIT) were conducted simultaneously from 18 May to 23 May 1994. For these tests, we released three groups of 100 treatment and control fish on three consecutive days (Appendix Table B-l). After marking and recovery, test fish were released between midday and late afternoon and recaptured on a continual 24-hour basis (Appendix Table B-3). Treatment fish for the canal injury test were transported to the release site in a 250-gallon transport tank and released 10 meters downstream of the headgates (Figure 3). Treatment fish for the screen injury test were released 10 meters upstream of the drum screens; these fish served as the control fish for the canal injury test. Control fish for the screen injury test were released in the bypass channel. For recapture at the downwell, we used the inclined plane trap used at Westland Canal in 1993 (Cameron et al. 1994).

Tests evaluating injury caused by passage through the downwell, bypass pipe and outlet (BOIT) were conducted from 10 May to 13 May 1994. We released three groups of 100 treatment and control fish on'three consecutive days (Appendix Table B-l). After marking and recovery, test fish were released between midday and early afternoon and recaptured until late-afternoon (Appendix Table B-3). Treatment groups for the bypass outlet injury test were released at the bypass channel weir; control fish were released into the trap at the bypass outlet (Figure 3). Trapping methods at the bypass outlet were analogous to those described for recapture at the Feed Canal bypass outlet.

At Stanfield Dam, we evaluated injury to fall chinook salmon that traveled through the ladder and fish entrance. Tests were conducted on 13 May and 14 May 1994 when the fish ladder operated according to low flow operation (without dam flashboards; APPENDIX A). We released three groups of 150 treatment and 100 control fish on each test date (Appendix Table B-l). Treatment fish were released within the ladder immediately downstream of the fish exit; control fish were released into the fyke net at the fish entrance (Figure 3). Recapture followed the same methods as those described for the ladder injury test at Feed Canal Dam.

Recovery and Travel Time

We followed the same methods for assessing travel time and percent recovery as described for Feed Canal Dam and Feed Canal. Travel distance for treatment fish in the canal, screen, and bypass outlet injury tests was 0.6 miles, 130 feet, and 460 feet, respectively.

Drum Screen Efficiency

We monitored passage of juvenile salmonids through (leakage) or over (impingement and roll-over) the drum screens at Furnish Canal from 18 April to 23 April using fingerling fall chinook salmon obtained from Umatilla Hatchery (Appendix Table B-2). The facility operated according to normal streamflow operation criteria with a bypass flow of 20 cfs during the test (APPENDIX A). Canal withdrawals were near maximum nominal flow, ranging from 107 cfs to 117 cfs (preliminary data).

We followed the same methods for assessing drum screen efficiency as described for Feed Canal, with several exceptions. We released fewer fish (Appendix Table B-l) and used two fyke nets to recapture test fish behind each drum screen. Release sites for test fish are shown in Figure 3. Mean size of test fish released upstream of the screens was 67.1 mm (Appendix Table C-2). We reused the fyke nets and frames from tests conducted at Westland Canal in 1993 (Cameron et al. 1994), with minor modifications. Two to four feet of netting was added to the mouth of the nets to improve deployment and capture retention. We lifted the fyke nets out of the water to collect their contents at approximately 12-hour intervals. After the nets were first checked at the start of the test, fish holding between the drum screen and fyke nets were crowded toward each net prior to lifting it out of the water. We cleaned the nets with pressurized water after each net pull. Data from the pair of nets behind each screen were pooled in the analysis of individual screen efficiency.

Velocity Measurements

In general, we followed the same methods to measure water velocity in front of the drum screens and at the bypass channel entrance at Furnish Canal on 2 May 1994 as described for Feed Canal. The fish bypass facility was operated according to normal streamflow operation criteria with a bypass flow of 20 cfs (APPENDIX A). Canal withdrawal was 112 cfs (preliminary data), approximately 75% of maximum nominal flow. Due to poor water clarity, we determined the vector of maximum velocity at 80% submerged screen depth using instantaneous velocity measurements with a time constant of two seconds. We switched the meter setting back to fixed point averaging at five-second intervals to collect velocity measurements. On 23 August 1994, we collected velocity measurements in front of the drum screens when canal flow was 78 cfs (52% of maximum nominal flow) and bypass flow was 0 cfs. Water clarity was good during this second set of measurements. We turned the 110-volt electrical drum screen motors off before collecting the measurements to reduce electromagnetic interference.

Westland Dam and Westland Canal

Injury

We evaluated injury to yearling summer steelhead and subyearling fall chinook associated with downstream passage through the fish ladder at Westland Dam. We tested two treatment effects -- passage through the ladder portion and passage through the auxiliary water portion of the ladder. Tests with summer steelhead were conducted on 16 April with one high flow (G-4) and one low flow (G-l) fish entrance gate open (Figure 4). Tests with fall chinook salmon were conducted on 26 May and 27 May with both high flow gates (G-3 and G-4) open. We maintained a one-foot head differential between the fish entrance pool and the dam tailwater during tests with both fish species. We did not operate the entrance gates according to operation criteria during tests with summer steelhead because of the need to effectively deploy the floating fyke net and optimize recapture (APPENDIX A). During tests with subyearling fall chinook salmon, we operated the fish ladder according to high flow operation criteria (with dam flashboards; APPENDIX A).

During tests with summer steelhead, we released three groups of 125 treatment fish and 100 control fish at hourly intervals during midday (Appendix Tables B-l and B-3). Treatment fish groups were released approximately two meters downstream of the fish exit and the auxiliary water intake (Figure 4). We released control fish groups approximately 0.5 meters upstream of Fish Entrance G-4 in the ladder entrance pool. We deployed the floating fyke net within 1.5 meters of Entrance G-4 to recapture the first release of test fish. For recapture of the second and third releases, we detached the trap floats and deployed the fyke net frame closer to and within 0.3 meters of the fish entrance.

During tests with fall chinook salmon, we released three groups each of 100 treatment and control fish at hourly intervals during early afternoon (Appendix Tables B-l and B-3). Release locations (Figure 4) and data analysis were the same as those used during tests with summer steelhead. Control fish were released approximately 0.5 meters upstream of Fish Entrances G-3 and G-4. To simultaneously recapture treatment and control fish passing through both fish entrances (G-3 and G-4), we deployed a large drum screen fyke net immediately downstream of the fish entrances, encompassing them both. We modified the cod end of the large fyke net for attachment to the live box of the floating fyke net. We used an air injection fish marking instrument (Panjet model SlA/F2) with a 50% aqueous solution of acrylic paint to give each group of test fish a unique subcutaneous mark on their ventral body surface (Starkie 1975).

For trap and haul injury (T&H), we evaluated injury to river-run subyearling chinook salmon associated with crowding, pumping, and pescalator loading procedures at the juvenile fish holding pond. We conducted tests to evaluate crowding and pump loading on 13 June, 14 June, and 17 June 1994. We evaluated combined injury caused by crowding and pescalator loading on 20 June 1994. We generally followed the same methods as described for the facility injury test at Furnish Canal.

For the pump-loading evaluation, we collected three 100-fish replicates on three separate dates from the pond before (control) and after (Treatment 1) crowding, and from the pump outflow (Treatment 2) after pumping (Appendix Table B-l). The replicates of control fish were collected near the pond inflow one-half hour prior to crowding. We collected fish for Treatments 1 and 2 at the beginning, middle, and end of the crowding and pumping procedures, respectively. All test fish were collected with a soft-meshed dip net. Fish marking and pre-test injury evaluation were not necessary with this injury test. We conducted T-tests for independent samples to determine whether injury was significantly greater for treatment fish than control fish ($P \leq 0.10$; Treatment 1 as the control for Treatment 2).

Pond conditions (fish densities) varied on a daily basis. Trap and haul personnel loaded 375 pounds, 200 pounds, and 50 pounds of fish on 13 June, 14 June, and 17 June, respectively. Most fish loaded on 14 June were crowded the previous day, but not loaded due to limited transport capabilities. Surface water temperature in the pond ranged from 58° F to 64° F when test fish were collected (0900 hours to 1000 hours).

For the pescalator evaluation, we collected test fish from the pond inflow with a large, soft-meshed dip net. We marked eight groups of 30 treatment fish and four groups of 25 to 30 control fish on their ventral body surface using the Panjet technique (Appendix Table B-l). We evaluated pre-test injury immediately after marking and held the groups of test fish until trap and haul personnel had cleared the pond. At five-minute intervals, we released a group of treatment fish into a 16-cubic-foot area at the mouth of the pescalator enclosed by a seine (l/4-inch mesh). We constricted the seine to crowd test fish into the mouth of the pescalator 34 minutes, 39 minutes, and 41 minutes after the final treatment release. For a total of 55 minutes, we netted treatment fish exiting the Pescalator tube, immediately prior to their passing over the dewatering screen. Treatment fish were collected over five-minute sampling intervals and held in 20-gallon containers. We released and recaptured control fish in the same location treatment fish were recaptured.

We conducted T-tests for independent samples to determine whether injury was significantly greater for treatment fish than control fish ($P \leq 0.10$). Surface water temperature in the pond was 60° F when test fish were collected (0900 hours).

Recovery and Travel Time

For fish passage through the ladder, we followed the same methods for assessing travel time and percent recovery as described for Feed Canal Dam and Feed Canal. Travel distances for passage (F-EX) and auxiliary water (AW) treatments were 96 feet and 85 feet, respectively.

For fish passage through the pescalator, we computed the mean time for 50% and 100% of recaptured treatment fish to travel through the pescalator. We computed mean percent recapture based on the number of treatment fish released.

Velocity Measurements

We generally followed the same methods to measure water velocity in front of the drum screens and at the bypass channel entrance at Westland Canal on 29 April 1994 as described for Feed Canal. The facility operated according to normal operation criteria (revised 13 April 1993; Cameron et al. 1994) with a bypass flow of approximately 24 cfs when velocity measurements were collected. Canal withdrawal (preliminary) was 214 cfs, approximately 76% of the reportedly maximum nominal flow at the screens. We turned the 110-volt drum screen motors off before collecting measurements to reduce electromagnetic interference.

Three Mile Falls Dam and West Extension Canal

Ladder Injury

We evaluated injury to subyearling fall chinook salmon associated with downstream passage through the east-bank adult fish passage facility at Three Mile Falls Dam. We conducted the test on 31 March and 1 April 1994 when the ladder was operated in a trapping mode with the high flow fish entrance gate (G-2) open (APPENDIX A). Combined flow through the passage and auxiliary water portions of the ladder was 183 cfs. Treatment group sizes (150 fish) were higher than control groups (100 fish) because we expected low recovery rates for treatment fish based on previous results (Appendix Table B-l; Cameron et al. 1994). We made three hourly releases of treatment and control fish on 31 March and one release on 1 April (Appendix Table B-3). Treatment fish were released in the passage portion of the ladder approximately two meters downstream of the fishway exit gate (Diffuser D-l), immediately downstream of Diffuser D-3, and at the crest of the auxiliary water weir (Gate G-3; Figure 5). We released control fish approximately one foot upstream of Fish Entrance G-2 in'the ladder entrance pool. Treatment and control group releases were paired, although control releases were split at two half-hour intervals. To recapture test fish, the floating fyke net was deployed downstream of Fish Entrance Gate G-2, using a pulley and winch system. In the data analysis, we used treatment groups released downstream of Diffuser D-3 as the control for treatment groups released upstream of Diffuser D-l. Fish released in the fyke net trap served as the control for treatment groups released downstream of Diffuser D-3 and at the auxiliary water weir. We used a paired T-test to determine whether injury was significantly greater for treatment fish.than control 'fish ($P \leq 0.10$).

Recovery

We followed the same methods for assessing travel time and percent recovery as described for Feed Canal Dam and Feed Canal. Travel distances for treatment fish released upstream of Diffuser D-l, downstream of Diffuser D-3, and at the auxiliary water weir were 210 feet, 150 feet, and 45 feet, respectively.

Velocity Measurements

We followed the same methods to measure water velocity in front of Diffuser D-l at the Three Mile Falls Dam fish ladder on 2 May 1994 as described for Feed Canal. Total flow through the ladder was 137 cfs. Measurements were taken at three depths along transects located at 16.7%, 33.3%, 50.0%, 56.7%, and 83.3% of the diffuser length. Sampling depths at each transect were 20%, 50%, and 80% of the water depth.

We also collected velocity measurements at one location in front of the left (facing downstream) Diffuser D-2 in the auxiliary water system of the fish ladder on 2 May 1994. The measurement was taken at a depth of one foot, approximately one foot in front of the diffuser and two feet from the left wall. We located the vector of maximum velocity using instantaneous velocity measurements with a time constant of two seconds. We switched the meter setting back to fixed point averaging to collect velocity measurements.

We followed the same methods to measure water velocity in front of the drum screens at West Extension Irrigation District Canal on 7 July 1994 as described for Feed Canal. However, the fish bypass facility was not operated according to normal operation criteria (Knapp and Ward 1990) because the bypass was closed. Canal withdrawal was estimated at 78 cfs (43% of maximum nominal flow); we could not use HYDROMET flow data because exchange pumping was occurring on 7 July and canal flow registered on the HYDROMET system accounted for both pumped and-withdrawn water. We turned the 110-volt electrical drum screen motors off before collecting the measurements. Due to poor water clarity, we located the vector of maximum velocity at 50% and 80% screen submergence depth using instantaneous velocity measurements with a time constant of two seconds. We switched the meter setting back to fixed point averaging to collect velocity measurements.

Video Honitoring

To monitor juvenile fish passing the fish exit gate at the Three Mile Falls Dam east-bank fish ladder, we investigated the feasibility of using an underwater video camera. We considered the physical and environmental requirements and constraints for a camera system at the site, including possible viewing locations, water velocity, depth and clarity, light penetration, desired camera viewing angles and file of view, and needs and availability of electrical power and protection areas for video recording and monitoring equipment.

We chose a miniature, low-light, remote camera system with waterproof housing (FIELDCAM) from Fuhrman Diversified, Inc. Low light sensitivity was provided by a CCD (charge coupled device) detector at the camera focus, which permitted image detection at a light intensity of 0.7 lux. Camera size (2.1 inches x 1.3 inches x 4.0 inches) was amenable to deployment in various locations without obstructing smolt passage. A standard 11-mm lens yielded a 35° viewing angle; an adaptable 3.6-mm lens permitted a wider, 105° viewing angle to potentially capture the full width of the fish exit gate. Image quality was enhanced with the high resolution camera and an ultra-high resolution monochrome monitor (12-inches diagonal). A waterproof cable supplied power from the 110-volt AC power supply to the remote camera. The system also included a real-time, 8-mm video recorder and playback deck to tape images for later viewing and analysis.

We designed an adjustable camera mount that could be deployed and operated in a variety of locations and would allow the capability of adjusting the camera's pitch while under water (Figure 7). Our design consisted of a 1.5-inch-diameter steel pipe at the bottom of which the camera was mounted. Cables connected to the camera body were wound onto spools mounted higher up on the pipe. Camera pitch was adjusted by hand turning the spools with a wrench. Further viewing adjustment occurred with rotation of the pipe. The camera cable was threaded through the steel pipe for protection. We constructed a support stand to hold the pipe in the desired position while video monitoring and recording. The monitor and recorder were housed within a weather-proof box to protect them from the elements while in the field and provide darkened conditions for in-field viewing.

We trial tested the video camera at the Furnish Canal bypass facility and the Three Mile Falls Dam east-bank fish ladder on 17 August and 2 September 1994, respectively. At Furnish Canal, the camera was deployed about six feet upstream of the bypass channel and behind Screen 7 between the screen and baffle boards. The camera was deployed about six feet upstream of the fish exit gate at the dam fish ladder. We primarily tested the performance and operation of the camera, mount, and support systems under existing environmental conditions.

Maxwell Canal

We followed the same methods to measure water velocity in front of the drum screens and at the bypass channel entrance at Maxwell Canal on 4 May 1994 as described for Feed Canal. The facility operated according to normal operation criteria with a bypass flow of approximately 9 cfs (Cameron et al. 1994). Canal withdrawal (preliminary) was 34 cfs, approximately 57% of maximum nominal flow. We turned the 110-volt electrical drum screen motors off before collecting the measurements to reduce electromagnetic interference.

Facility Monitoring

Surveys to detect and document juvenile salmonid passage problems or concerns at ladder and bypass facilities were conducted intermittently at all diversion sites during periods of water withdrawal and smolt outmigrations. We recorded any notable observations of fish stranding, leakage through or impingement on screen structures, facility operations out of criteria, and effects of abnormal river or canal flow events on passage conditions. We also noted passage impediments, facility defects or constraints, and maintenance problems as related to fish passage.

Surveys at juvenile salmonid bypass facilities involved the inspection of structural components such as headgates, trash racks, drum screens, bypass weirs and gates, traveling screens, and outlet structures. We also noted other factors that either directly or indirectly affect fish passage through bypass facilities, such as river flow, canal elevation, debris loading, turbidity, siltation, and water temperature.

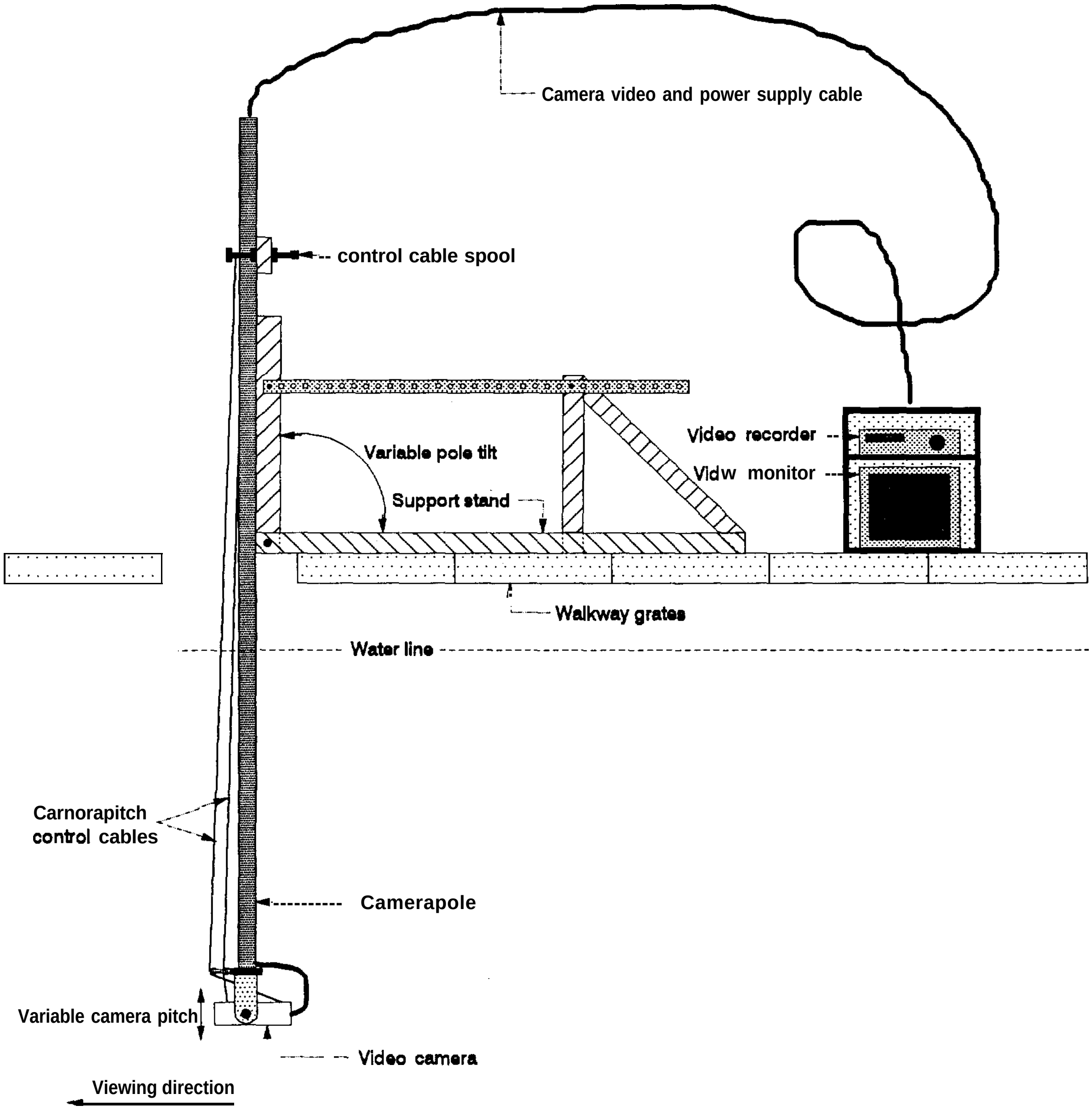


Figure 7. Underwater video camera system and support equipment, Umatilla River, 1994.

Surveys at adult salmonid passage facilities (fish ladders) were conducted to document present or potential hazards to juvenile outmigrants passing downstream through these structures. We recorded ladder entrance and exit gate configurations, outside and inside pool elevations, attraction water weir setting (if any), and debris accumulation on diffuser grates and trash racks.

RESULTS

Feed Canal Dam and Feed Canal

Injury

Yearling spring chinook salmon traveling from the headgates, past the screens and through the downwell, bypass pipe, and outlet at Feed Canal received statistically significant injury ($P = 0.01$; Table 1). However, the difference in mean, net weighted injury between treatment and control fish was only 3.6, attributable to increases in low partly descaled (11.2%) and descaled (3.0%) treatment fish compared to control fish. Variation among injury rates for treatment groups ($s^2 = 17.9$) was significantly different ($P = 0.02$) from control groups ($s^2 = 2.8$). Non-parametric analysis (Wilcoxon signed rank test) also indicated treatment injury was significantly greater than control injury ($P = 0.02$). Other injuries recorded prior to release and after recapture consisted almost exclusively of bloody eyes.

Yearling spring chinook salmon that passed through the ladder at Feed Canal Dam received few injuries (Table 1). Although, the difference in mean, net weighted injury between treatment and control fish was nearly statistically significant ($P = 0.13$), the magnitude of this difference was small (1.5). Net weighted injury rates were very low for four of six replicate treatment groups (-2.2 to 0.8) and moderate for the remaining two groups (4.2 to 5.5). Variation in injury rates of treatment ($s^2 = 7.0$) and control ($s^2 = 5.8$) replicate groups was low and not significantly different ($P = 0.84$). Treatment fish incurred a slight increase in moderate partial descaling (4.0%) and full descaling (0.5%) over that of control fish.

Recovery and Travel Time

Due to low recovery rates for treatment fish, we were not able to determine 50% and 95% travel times for yearling spring chinook salmon passage from the headworks canal to the outlet at Feed Canal (Table 2). Percent recapture among replicate treatment groups ranged from 13% to 35%. Capture efficiency for the outlet trap (mean = 94.6%, SD = 4.0) was too high to account for the low recovery rates. Sampling duration averaged 4.5 hours per day, extending from near noon to dusk. Recapture of treatment fish was slow and generally steady during all releases. Mean percent recapture at the conclusion of testing was 26.9%.

Yearling spring chinook salmon traveled quickly through the ladder at Feed Canal Dam. Mean time to recapture 50% (median travel time) of the treatment fish released immediately downstream of the fish exit was 4.8 minutes (Table 2). Few additional fish were recaptured when sampling was

Table 1. Results of injury tests conducted at juvenile fish bypasses and adult fish ladders associated with Feed Canal and Stanfield dams during the 1994 Umatilla River juvenile fish passage evaluation (pre-test values are in parentheses; N = number of test replicates).

Species[a]	Test[b]	Treatment or control[c]	Number released	Number recaptured	Mean percentage of fish recaptured: Low descaling	Moderate descaling	Oescaled	Other	Mortality	Treatment minus control: Mean net weighted injury	90% confidence limit	Probability[d]	N
FEED CANAL FISH BYPASS FACILITY													
CHS	FIT	Treatment	889	239	33.2 (16.1)	7.5 (2.3)	7.0 (0.2)	1.6 (0.4)	0.0 (0.0)	3.6	± 1.8	p = 0.01	9
CHS	FIT	Control	875	828	22.0 (17.2)	8.6 (2.2)	4.0 (0.2)	1.2 (0.8)	0.1 (0.0)				9
FEED CANAL DAM FISH LAOOER													
CHS	LIT	Treatment	600	356	46.6 (35.4)	6.1 (0.0)	1.1 (0.0)	0.2 (0.8)	0.0 (0.0)	1.5	± 1.7	p = 0.13	6
CHS	LIT	Control	599	362	44.8 (32.8)	2.1 (0.0)	0.6 (0.0)	0.0 (1.0)	0.0 (0.0)				6
FURNISH CANAL FISH BYPASS FACILITY													
CHF	CIT	Treatment	896	661	74.6 (71.2)	2.4 (0.7)	0.3 (0.0)	0.0 (0.0)	0.0 (0.0)	1.3	± 0.9	p = 0.13	9
CHF	SIT	Treatment	885	753	75.0 (73.6)	1.1 (0.2)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	-0.7	± 1.0	p > 0.50	9
CHF	SIT	Control	887	a94	76.0 (72.3)	1.7 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)				9
CHF	BOIT	Treatment	876	846	7.1 (4.1)	0.0 (0.1)	0.0 (0.0)	0.7 (0.3)	0.0 (0.0)	0.3	± 0.4	p = 0.19	9
CHF	BOIT	Control	868	838	6.2 (4.9)	0.6 (0.1)	0.0 (0.0)	0.7 (0.1)	0.0 (0.0)				9
STANFIELD DAM FISH LADDER													
CHF	LIT	Treatment	a94	649	29.2 (15.7)	7.8 (0.3)	1.3 (0.0)	0.0 (0.0)	0.1 (0.0)	0.3	± 1.9	p = 0.40	6
CHF	LIT	Control	590	448	25.9 (12.8)	6.6 (0.8)	0.7 (0.0)	0.0 (0.5)	0.8 (0.0)				6

[a] CHS = yearling spring chinook salmon, CHF = subyearling fall chinook salmon.
[b] FIT = facility injury test, LIT = ladder injury test, CIT = canal injury test, SIT = screen injury test, BOIT = bypass outlet injury test.
[c] SIT treatment was the control for CIT treatment.
[d] Risk of error for rejecting H_o: (T - C) = 0 in favor of alternative H_a: (T - C) > 0.

Table 2. Travel time, determined as the number of hours to recapture 50 percent (median) and 95 percent of test fish released, and the percentage of test fish recaptured by the end of each test at fish bypass and ladder facilities at Feed Canal and Stanfield dams, Umatilla River, spring 1994.

Species	Bypass section	Release site[a]	Capture site[b]	Bypass flow (cfs)	Canal flow (cfs)	50% Travel time (hours)			95% Travel time (hours)			Percent recapture		
						mean	SD	N	mean	SD	N	mean	SD	N
FEED CANAL FISH BYPASS FACILITY														
CHF	Upper/Lower	HWC	OT	18	215-242	--	--	--		--	-	26.9	8.3	9
FURNISH CANAL FISH BYPASS FACILITY														
CHF	Upper	D-H	DT	20	79-84	2.03	.54	9	8.2	2.8	5	94.0	5.1	9
CHF	Upper	U-DS	DT	20	79-84	.55	.28	9	8.2	2.6	9	98.8	1.9	9
CHF	Lower	BCW	OT	20	79-84	.31	.31	9	.48	.28	7	96.7	5.4	9
FEED CANAL DAM FISH LADDER														
CHS	--	F-EX	F-EN	--	--	.08	.02	5	--	--	--	58.7	7.03	6
STANFIELD DAM FISH LADDER														
CHF	--	F-EX	F-EN	--	--	.20	.25	6	--	--	--	72.5	7.6	6

[a] *HWC = headworks canal, U-DS = 15 m upstream of drum screens, D-H = 15 m downstream of headgates, BCW = bypass channel weir, F-EX = fish exit.*

[b] *OT = outfall trap, DT = downwell trap, F-EN = fish entrance,*

continued beyond 18 minutes after release. Mean percent recapture of treatment fish (58.7%) was nearly the same as capture efficiency of the trap **(60.3%),** as determined from control fish releases.

Drum Screen Efficiency .

Drum screens at Feed Canal were highly efficient at preventing fall chinook salmon fingerlings from entering the canal (Table 3) when canal withdrawals were near maximum (208 cfs to 215 cfs). However, some fish leakage was observed at seven of 10 screens, especially Screen 3. Correcting for fyke net efficiency adjusted the number of fish recaptured behind Screen 3 to four. Fyke net efficiency at Screen 3 (48%) was the lowest and most variable (range = 4% to 90%) of any of the nets. Screen efficiencies ranged from 99.85% to 100%. Overall screening efficiency was 99.95% (Table 3). Mean fork length of fish that leaked through the screens (mean = 63.0 mm, SD = 5.6) was not significantly smaller ($P > 0.40$) than the mean size of treatment fish released upstream of the screens (mean = 64.1 mm, SD = 3.8; Appendix Table C-u . No impingement or roll-over was observed during testing.

Maximum and minimum temperatures ranged from **42°F** to **52°F** during the test period (Appendix Figure C-l). Most test fish moved past the screens in the afternoon and early evening when water temperatures were near the daily maximum.

Velocity Measurements

At normal operating criteria, the headworks elevation at Feed Canal was 655.9 feet to 656.0 feet; 1.4 feet to 1.5 feet of spill (17 to 18 cfs) passed over the bypass weir. Water velocities measured in front of the drum screens on two consecutive days were in close agreement (Tables 4 and 5). In addition, estimated canal flows from velocity measurements and wetted screen surface area were within 5% of preliminary HYDROMET readings. Approach velocity criteria for fry (≤ 0.4 fps) and fingerlings (I 0.8 fps) was met at 42% and 98% of the 90 sampling locations, respectively. All approach velocities greater than 0.8 fps were measured at the 50% submerged depth of Screens 8 and **10.** Overall, approach velocities were fairly uniform among depths. Mean approach velocity by submerged screen depth ranged from 0.52 fps (50% depth) to 0.37 fps (80% depth). Both mean estimated flow and mean approach velocity were notably lower through upstream Screens 1 - 3 (15.94 cfs, 0.36 fps) than through downstream Screens 4 - 10 (21.75 cfs, 0.49 fps).

Sweep velocities in front of the drum screens generally ranged between 1 fps to 2 fps and were at least twice the approach velocity (Tables 4 and 5). Abnormally low sweep velocities (≤ 0.45 fps) were recorded at all sampling depths along the upstream transect of Screen 1. Sweep velocity at **screens'** increased with their proximity to the bypass channel.

The headworks elevation was 655.9 feet and 1.4 feet of spill (17 cfs) passed over the bypass weir when velocity measurements were collected at the bypass channel. Mean approach velocity at the bypass channel entrance was 2.24 fps (SD = 0.14; Table 5). Approach velocity at 20% (2.28 fps) and 50%

Table 3. Estimates of drum screen efficiency at the Feed and Furnish canal juvenile fish bypass facilities, Umatilla River, spring 1994.

	FEED CANAL			FURNISH CANAL		
Drum screen no.	Mean fvke net efficiency (Percent)	Screen efficiency (percent)	Corrected leakage & mean fork length (mm)	Mean fyke net efficiency (percent)	Screen efficiency (percent)	Corrected leakage & mean fork length (mm)
1	93	99.96	1 (56)	76	100	--
2	70	100	--	86	100	--
3	48	99.85	4 (61)	61	100	--
4	72	99.95	1 (NA)	84	100	--
5	92	99.92	2 (NA)	81	100	--
6	97	100	--	73	100	--
7	73	99.90	2 (67)	61	99.88	2 (60)
8	100	99.93	2 (68)	--	--	--
9	97	99.96	1 (NA)	--	--	--
10	99	100	--	--	--	--
Overall efficiency:	84.1	99.95	1.3 (63.0)	75	99.99	0.3 (60)
Range						
Minimum:	4	99.5	0 (56)	25	99.9	0 (--)
Maximum:	100	100	2 (68)	97	100	1 (60)

Table 4. Mean sweep and approach velocities (fps) at the Feed Canal drum screens, Umatilla River, 13 April 1994. Drum screens are numbered in ascending order from upstream to downstream. Bypass flow was 18 cfs.

Drum screen no.	Transect	Sweep velocity Percent of screen submergence 20%	50%	80%	Approach velocity Percent of screen submergence 20%	50%	80%
1	Upstream	.22	.04	.02	.45	.68	.20
2	Upstream	1.32	1.27	.97	.33	.59	.28
3	Upstream	1.62	1.51	1.12	.29	.46	.22
4	Upstream	1.74	1.73	1.37	.63	.63	.30
5	Upstream	1.98	1.61	1.69	.61	.62	.30
6	Upstream	1.91	1.79	1.21	.20	.69	.49
7	Upstream	1.80	1.69	1.43	.55	.33	.25
8	Upstream	1.92	1.91	1.44	.62	.85	.41
9	Upstream	2.15	2.00	1.07	.42	.65	.27
10	Upstream	2.04	2.03	1.51	.47	.62	.52
1	Middle	1.10	.53	.15	.30	.44	.03
2	Middle	1.20	1.39	.94	.32	.50	.29
3	Middle	1.76	1.44	.95	.31	.41	.24
4	Middle	1.75	1.41	1.01	.67	.57	.29
5	Middle	1.68	1.33	1.36	.51	.48	.36
6	Middle	1.89	1.49	1.29	.20	.66	.55
7	Middle	1.93	1.50	.84	.37	.37	.29
8	Middle	2.10	1.55	1.21	.33	1.01	.30
9	Middle	2.01	1.97	1.16	.58	.38	.31
10	Middle	1.85	1.80	1.52	.43	.32	.41
1	Downstream	1.06	.71	.43	.28	.67	.18
2	Downstream	1.32	1.36	.88	.26	.31	.24
3	Downstream	1.66	1.34	.71	.38	.36	.33
4	Downstream	1.74	1.38	1.06	.67	.67	.41
5	Downstream	1.74	1.32	1.04	.53	.79	.46
6	Downstream	1.77	1.60	1.13	.54	.71	.41
7	Downstream	1.95	1.79	.74	.38	.51	.23
8	Downstream	2.11	1.66	1.04	.41	.60	.32
9	Downstream	1.94	1.80	.52	.56	.48	.24
10	Downstream	1.66	1.80	1.52	.54	.52	.41

Canal flow measured at HYDROMET gauging station (FCEO) = 210.0 cfs.
Canal flow estimated with velocity measurements = 199.4 cfs.

Table 5. Mean sweep and approach velocities (fps) at the Feed Canal drum screens, Umatilla River, 14 April 1994. Drum screens are numbered in ascending order from upstream to downstream. Bypass flow was 17 cfs.

Drum screen no.	Transect	Sweep velocity Percent of screen submergence			Approach velocity Percent of screen submergence		
		20%	50%	80%	20%	50%	80%
1	Upstream	.18	.40	.45	.62	.43	.21
2	Upstream	1.22	1.27	1.02	.24	.20	.29
3	Upstream	1.62	1.25	1.19	.49	.43	.28
4	Upstream	1.77	1.40	1.25	.47	.57	.56
5	Upstream	1.77	1.75	1.29	.51	.47	.50
6	Upstream	1.81	1.56	1.34	.39	.51	.66
7	Upstream	1.86	1.84	1.09	.53	.53	.51
8	Upstream	2.04	1.76	1.47	.36	.50	.42
9	Upstream	2.01	1.85	1.25	.65	.60	.38
10	Upstream	1.85	1.71	1.22	.67	.91	.60
1	Middle	.97	.45	.16	.41	.19	.39
2	Middle	1.57	1.34	.94	.33	.51	.25
3	Middle	1.60	1.08	.92	.43	.33	.34
4	Middle	1.76	1.40	.91	.41	.51	.53
5	Middle	1.81	1.57	1.25	.48	.51	.58
6	Middle	1.75	1.65	1.73	.37	.44	.63
7	Middle	1.77	1.77	1.28	.48	.48	.37
8	Middle	1.86	1.64	1.08	.33	.50	.41
9	Middle	1.89	1.59	1.19	.58	.52	.34
10	Middle	1.72	1.61	1.48	.63	.82	.75
1	Downstream	1.07	.90	.12	.25	.42	.43
2	Downstream	1.52	1.23	.80	.29	.47	.29
3	Downstream	1.55	1.10	.93	.47	.36	.15
4	Downstream	1.60	1.35	.91	.37	.49	.39
5	Downstream	1.73	1.52	1.18	.37	.29	.25
6	Downstream	1.67	1.41	1.06	.23	.38	.30
7	Downstream	1.76	1.70	1.07	.50	.46	.31
8	Downstream	1.86	1.43	1.03	.33	.36	.40
9	Downstream	1.77	1.61	.65	.64	.52	.20
10	Downstream	1.66	1.62	1.45	.54	.53	.65

Canal flow measured at HYDROMET gauging station (FCEO) = 205.0 cfs
Canal flow estimated with velocity measurements = 196.3 cfs

Approach velocity at bypass channel entrance: 2.28[a] 2.36[a] 2.10[a]

[a] *Measurements collected at 20%, 50%, and 80% of water depth.*

(2.36 fps) sampling depths were approximately 28% higher than approach velocity at the 80% (2.10 fps) sampling depth.

Stanfield Dam and Furnish Canal

Injury

The Furnish Canal juvenile fish bypass facility caused few injuries to fall chinook salmon test fish that traveled through the headworks canal, past the screens, and through the downwell, bypass pipe, and outlet when canal flow was 67% of maximum and bypass flow was at maximum. Although injury caused by passage through the headworks canal (CIT) was nearly statistically significant (P = 0.13), results were attributable to small proportional increases in low partly descaled (2.0%), moderate partly descaled (0.8%) and descaled (0.3%) test fish over control fish injury levels (Table 1). Injury to test fish caused by movement past the screens (SIT) was undetectable (P > 0.5). In this test, we calculated a negative difference in treatment minus control mean, net weighted injury rates (-0.7). Fish traveling through the downwell and bypass pipe also did not receive statistically significant injury (P = 0.19).

The Stanfield Dam fish ladder caused few injuries to subyearling fall chinook salmon that traveled from approximately three meters downstream of the fish exit, through the ladder, and out the low flow fish entrance (G-2). Mean net weighted injury was not significantly greater for treatment fish than control fish (P = 0.40; Table 1).

Recovery and Travel Time

In the upper bypass, 95% of the test fish from 5 of 9 fish groups released 15 meters downstream of the headgates were recaptured in 8.2 hours (95% travel time; Table 2). Mean percent recapture for all nine fish groups at the conclusion of testing was 94.0%. Time for 50% of the test fish released downstream of the headgates to travel through the 0.6-mile headworks canal and past the drum screens was 2.03 hours. For test fish released 15 meters upstream of the drum screens, approximately 0.55 hours elapsed for 50% of these fish to be recaptured at the downwell. Movement of test fish through the downwell and bypass pipe was quickest. Median travel time from the bypass channel weir to the bypass outlet was 0.31 hours. Mean recapture of all test fish released at the bypass channel weir was 96.7% at the conclusion of the test. We operated our outlet trap an average of 2.01 hours after the first release of test fish.

Subyearling fall chinook salmon traveled quickly through the ladder at Stanfield Dam as median travel time was only 12.0 minutes for treatment fish released downstream of the fish exit (Table 2). Mean percent recapture of treatment fish (72.5%) was nearly the same as capture efficiency of the trap (75.9%) as determined by capture rates of control fish.

Drum Screen Efficiency

Drum screens at Furnish Canal almost completely prevented fall chinook salmon fish from entering the canal when canal withdrawals were near maximum nominal flow (107 cfs to 117 cfs). Leakage was only observed at Screen 7 (1 fish). A correction for fyke net efficiency (61%) estimated two fish leaked through the screen (Table 3). Fork length of the leaked fish (60 mm) was approximately 7 mm less than the mean fork length of test fish released upstream of the screens (Appendix Table C-2). Overall screening efficiency for the seven screens combined was 99.99% (Table 3). Mean capture efficiency for all fyke nets was 75% and on individual dates ranged from 25% to 97%. No impingement or roll-over was observed during testing.

Minimum and maximum water temperatures ranged from 44° F to 58° F during the test period (Appendix Figure C-l). Most test fish moved past the screens in the afternoon and early evening when water temperatures were near the daily maximum.

Velocity Measurements

Canal flow estimated from mean approach velocity measured in front of the drum screens was 29% higher than preliminary HYDROMET readings (Table 6). Approach velocity criteria for fry (≤ 0.4 fps) and fingerlings (≤ 0.8 fps) was met at 56% and 100% of the sampling locations, respectively. Highest approach velocities were measured at the 80% submerged screen depths of Screens 1 - 4 and at the 50% and 80% submerged screen depths of Screen 7. Mean approach velocity by submerged screen depth ranged from a high of 0.46 fps at 80% depth to a low of 0.34 fps at the 20% depth. Mean estimated flow and mean approach velocity were higher through Screens 3, 4 and 7 (24.27 cfs, 0.47 fps) than through Screens 1, 2, 5 and 6 (17.98 cfs, 0.35 fps).

Sweep velocities in front of the drum screens ranged from 0.97 fps to 1.65 fps (Table 6). Sweep velocity was at least twice the approach velocity in all, but three sampling locations; these locations were at the 80% submerged screen depth at Screens 1 and 4. Sweep velocity at screens generally increased with their proximity to the bypass channel.

Mean approach velocity at the bypass channel entrance was 2.65 fps (SD = 0.07) during a 20 cfs bypass flow. Approach velocity was uniform among sampling depths (Table 6).

Results of velocity measurements collected during low canal flow are presented in Appendix Table C-3.

Westland Dam and Westland Canal

Injury

Injury tests with subyearling fall chinook salmon at the Westland Dam fish ladder during high flow operation indicated movement through the auxiliary water portion of the ladder caused injury to test fish, but movement

Table 6. Mean sweep and approach velocities (fps) at the Furnish Canal drum screens, Umatilla River, 2 May 1994. Drum screens are numbered in ascending order from upstream to downstream. Bypass flow was 20 cfs.

Drum screen no.	Transect	Sweep velocity Percent of screen submergence 20%	 50%	 80%	Approach velocity Percent of screen submergence 20%	 50%	 80%
1	Upstream	1.06	1.12	1.06	.30	.43	.69
2	Upstream	1.19	1.23	1.17	.32	.33	.50
3	Upstream	1.44	1.35	1.29	.31	.36	.63
4	Upstream	1.21	1.47	1.16	.32	.45	.75
5	Upstream	1.58	1.65	1.56	.42	.44	.25
6	Upstream	1.65	1.40	1.22	.29	.45	.06
7	Upstream	1.57	1.45	1.36	.31	.62	.52
1	Middle	1.12	1.16	1.00	.30	.29	.65
2	Middle	1.28	1.23	1.04	.37	.33	.46
3	Middle	1.48	1.37	1.26	.29	.37	.64
4	Middle	1.51	1.46	1.31	.38	.44	.64
5	Middle	1.52	1.50	1.45	.41	.40	.26
6	Middle	1.59	1.41	1.21	.25	.43	.21
7	Middle	1.61	1.36	1.36	.28	.61	.69
1	Downstream	1.01	1.15	.97	.27	.20	.37
2	Downstream	1.32	1.24	1.09	.35	.36	.46
3	Downstream	1.37	1.38	1.22	.45	.40	.40
4	Downstream	1.50	1.46	1.19	.29	.45	.58
5	Downstream	1.49	1.44	1.38	.37	.41	.14
6	Downstream	1.55	1.34	1.15	.22	.46	.29
7	Downstream	1.45	1.51	1.54	.56	.58	.53

Canal flow measured at HYDROMET gauging station (FURO) = 112.0 cfs
Canal flow estimated with velocity measurements = 144.3 cfs

Approach velocity at bypass channel entrance: 2.65[a] 2.65[a] 2.66[a]

[a] *Measurements collected at 20%, 50%, and 80% of water depth.*

through the passage portion did not. The difference in mean, net weighted injury between treatment fish released at the auxiliary water weir (treatment AWW) and control fish released in the trap was moderate (2.7), but still high enough to be statistically significant (P = 0.05; Table 7). Injury caused by passage through the auxiliary water system consisted of moderate increases in proportions of low partly descaled (7.6%), moderate partly descaled (3.1%), and descaled (1.4%) test fish over control fish injury rates. Injury caused by movement through the passage portion of the ladder (treatment F-EX) was less than control fish injury rates (P > 0.5). Data analysis was not conducted on the results of the ladder injury test with summer steelhead due to low recovery of treatment fish.

Trap and haul fish loading procedures at Westland Canal, using either a Neilson fish pump or pescalator, caused few injuries to subyearling chinook salmon (Table 7). We were not able to detect statistically significant injury caused by fish crowding or pump-loading (P > 0.5). Differences in treatment and control mean weighted injury rates were negative for both the crowding (-0.9) and pumping (-0.1) procedures. In both cases, treatment injury was small compared with the variability of injury rates of control fish. The difference in mean net weighted injury between pescalator treatment and control fish was small (0.3) and not significantly greater than zero (P = 0.35).

Recovery and Travel Time

Subyearling fall chinook salmon traveled through the passage portion of the Westland Dam fish ladder quicker, and were recovered at a higher rate, than fish traveling through the auxiliary water system. Median travel- time through the passage side (0.12 hours) was about one-third the median travel time through the auxiliary water side (0.36 hours; Table 8). Time to recapture 95% of the three treatment groups traveling through the passage side (0.41 hours) was nearly equal to the 50% recapture time of treatment fish traveling through the auxiliary water side. Ninety-five percent recapture was not reached for any of the replicate groups that traveled through the auxiliary water system. However, mean percent recapture at the conclusion of the test was high for both the passage treatment (95.8%) and the attraction water treatment (89.3%) groups. Trap capture efficiency, determined from recapture rates of control fish, was 87.8%.

Recapture rates of summer steelhead released downstream of the fish exit (1.8%) and upstream of the auxiliary water weir (1.1%) were very low. Mean recapture rate for control groups released at the fyke net mouth was 71.1%.

Fish loading was slow with the pescalator set at full speed and with low fish densities. Time for 50% and 100% of the subyearling chinook salmon entering the mouth of the pescalator to be transported to the exit was 22.9 minutes and 36.0 minutes, respectively (Table 8). Of the fish released in the seined area, 83.6% were recaptured at the top of the pescalator.

Table 7. Results of injury tests conducted at juvenile fish bypass facilities and associated with Westland and Three Mile Falls dams during the 1994 Umatilla River j evaluation (pre-test values are in parentheses; N = number of test replicates).

Species[a]	Test[b]	Treatment[c] or control	Release[d] site	Number released	Number recaptured	Mean oercentase of fish recaptured: Low descaling	Moderate descaling	Descaled	Other	Mortality	T Mea we i
FISH LADDER AT WESTLAND DAM											
CHF	LIT	Treatment	F-Ex	591	522	58.4 (56.6)	3.7 (0.0)	0.3 (0.0)	0.0 (0.0)	0.0 (0.0)	
CHF	LIT	Treatment	AWW	593	394	61.0 (51.5)	8.1 (0.0)	1.2 (0.0)	0.0 (0.0)	0.0 (0.0)	
CHF	LIT	Control	F-En	583	423	60.5 (58.6)	5.3 (0.3)	0.5 (0.7)	0.0 (0.0)	0.0 (0.0)	
JUVENILE FISH BYPASS FACILITY AT WESTLANO DAM											
CHF	T&H	Treatment (Pump)		--	902	18.4	3.4	1.8	0.4	0.0	
CHF	T&H	Treatment (Crowd)		--	900	22.0	2.0	1.8	0.3	0.0	
CHF	T&H	Control (Pond)		--	901	23.9	3.8	1.9	0.2	0.0	
CHF	T&H	Treatment (Pescalator)		240	201	38.1 (31.7)	2.4 (2.9)	0.5 (0.0)'	0.4 (0.0)	0.0 (0.0)	
CHF	T&H	Control		110	105	24.0 (20.7)	1.0 (2.0)	1.1 (0.0)	0.0 (0.0)	0.0 (0.0)	
FISH LADDER AT THREE MILE FALLS DAM											
CHS	LIT	Treatment	UD-1	590	43	40.7 (38.0)	8.6 (3.8)	16.9 (0.7)	0.0 (0.7)	0.0 (0.0)	
CHS	LIT	Treatment	DD-3	594	260	51.0 (45.2)	21.1 (2.3)	6.3 (0.0)	0.6 (1.0)	0.0 (0.0)	
CHS	LIT	Treatment	AW	595	176	46.3 (42.1)	19.7 (2.7)	10.4 (0.0)	1.0 (1.8)	0.0 (0.0)	
CHS	LIT	Control	F-En	389	345	46.1 (46.3)	21.1 (1.3)	11.9 (0.7)	0.0 (1.7)	0.3 (0.0)	

[a] CHS = yearling spring chinook salmon, CHF = subyearling fall chinook salmon.
[b] LIT = ladder injury test, T&H = trap & haul pump or pescalator test.
[c] Treatment DD-3 was the control for Treatment UD-1, treatment (crowd) was the control for treatment (pump).
[d] F-Ex = fish exit, AW = Auxiliary water system, F-En = fish entrance gate, UD-1 = upstream of Diffuser D-l, DI
AWW = auxillary water weir, .
[e] Risk of error for rejecting H_o: $(T - C) = 0$ in favor of alternative H_a: $(T - C) > 0$.
[f] Mean weighted injury.

Table 8. Travel time, determined as the number of hours to recapture 50 % (median) and 95 % of test fish released and the percentage of test fish recaptured by the end of each test at the Westland and Three Mile Falls dam fish ladders; 50% and 100% travel time for fish in the pescalator at Westland Canal, Umatilla River, spring 1994.

Species	Bypass section	Release site[a]	Capture site[b]	Bypass flow (cfs)	Canal flow (cfs)	50% Travel time (hours) mean	50% Travel time (hours) SD	50% Travel time (hours) N	95% Travel time (hours) mean	95% Travel time (hours) SD	95% Travel time (hours) N	Percent recapture mean	Percent recapture SD	Percent recapture N
WESTLAND DAM FISH LADDER														
CHF	--	F-EX	F-EN	--	--	.12	.11	4	.41	.22	4	95.8	5.4	4
CHF	--	U-AW	F-EN	--	--	.36	.34	4	--	--	--	89.3	5.2	4
WESTLAND CANAL FISH BYPASS FACILITY														
CHF	--	P-M	P-EX	--	--	.38	.17	8	.60[c]	.19	8	83.6[d]	6.1	8
THREE MILE FALLS DAM FISH LADDER														
CHS	--	U-D1	F-EN	--	--	--	--	-	--	--	--	9.3	6.2	4
CHS	--	D-D3	F-EN	--	--	--	--	-	--	--	--	44.0	10.1	4
CHS	--	AWW	F-EN	--	--	--	--	-	--	--	--	29.8	11.3	4

[a] *F-EX = fish exit, F-EN = fish entrance, AW = 5 m upstream of auxilary water weir, P-M = pescalator mouth, U-D1 = upstream of Diffuser D-l, D-D3 = downstream of Diffuser D-3, AWW = auxilary water weir.*
[b] *F-EN = fish entrance, P-EX = pescalator exit.*
[c] *100% travel time.*
[d] *Percent loading efficiency.*

Velocity Heasurements

Canal flow estimated from mean approach velocity measured in front of the drum screens was 18% lower than preliminary HYDROMET readings (Table 9). Approach velocity criteria for fry ($\leq$ 0.4 fps) and fingerlings (I 0.8 fps) was met at 90% and 100% of the 90 sampling locations, respectively. Highest approach velocity measured was 0.56 fps at Screen 10 (middle transect, 20% submerged screen depth). Approach velocity was fairly uniform among depths and screens, ranging from a mean of 0.28 fps to 0.32 fps among sampling depths and from 0.25 fps to 0.36 fps among screens.

Sweep velocities in front of the drum screens ranged from 0.79 fps to 1.66 fps; most were higher than 1.20 fps (77% of sampling locations; Table 10). Sweep velocity was at least twice the approach velocity at all sampling locations. Sweep velocities were fairly uniform between 20% and 50% submerged screen depths, and slightly lower at the 80% depth. Mean sweep velocities at individual screens were highest at middle Screens 4 - 8 (range = 1.41 fps to 1.53 fps). For the remaining screens (1, 2, 3, 9, 10), sweep velocity gradually decreased with distance away from the middle screens (range = 0.98 fps to 1.37 fps).

Mean approach velocity at the bypass channel entrance was 2.10 fps (SD = 0.05) during a 24-cfs bypass flow. Approach velocity was fairly uniform among sampling depths in the bypass channel (Table 9).

Three Mile Falls Dam and West Extension Canal

Injury

Low recapture rates for spring chinook salmon released in the east-bank ladder injury test affected the reliability of results. Low recapture rates were adequate for analysis of injury incurred by treatment fish released downstream of Diffuser D-3 and at the auxiliary water weir. But recapture of treatment fish released upstream of Diffuser D-l was too low to provide conclusive results. Only 45 of 590 (7.6%) treatment fish released upstream of the fish exit gate (UD-1) were recaptured (Table 7). From 2 to 24 fish were recaptured from replicate groups released at this site; the replicate with two fish was removed from the data analysis. Based on small sample sizes, injury caused by passage through the fish exit gate (Diffuser D-l) and Diffuser D-3 was not significantly greater (P = 0.32) than injury to fish that were released downstream of Diffuser D-3. Trap and handling-caused injury was greater for control fish (F-EN) than for treatment fish released downstream of Diffuser D-3 (DD-3) or at the auxiliary water weir (AW). As a result, mean net weighted injury rates were negative for both of these treatments and tests were not statistically significant ($P > 0.5$; Table 7).

Recovery

Mean percent recapture of yearling spring chinook salmon was low for treatment fish released upstream of Diffuser D-l (9.3%), but improved for treatment fish released at the auxiliary water weir (29.8%) and downstream of Diffuser D-3 (44.0%; Table 8). Sampling duration from time of first test fish

Table 9. Mean sweep and approach velocities (fps) at the Westland Canal drum screens, Umatilla River, 29 April 1994. Drum screens are numbered in ascending order from upstream to downstream. Bypass flow was 24 cfs.

Drum screen no.	Transect	Sweep velocity, Percent of screen submergence			Approach velocity, Percent of screen submergence		
		20%	50%	80%	20%	50%	80%
1	Upstream	1.08	1.06	.84	.21	.51	.39
2	Upstream	1.48	1.25	.96	.29	.38	.39
3	Upstream	1.46	1.27	1.09	.18	.29	.31
4	Upstream	1.24	1.57	1.29	.31	.28	.37
5	Upstream	1.41	1.58	1.33	.49	.31	.28
6	Upstream	1.62	1.63	1.56	.29	.38	.30
7	Upstream	1.66	1.66	1.45	.32	.44	.28
8	Upstream	1.64	1.57	1.29	.26	.31	.27
9	Upstream	1.53	1.54	1.38	.24	.38	.37
10	Upstream	1.43	1.37	1.29	.20	.37	.20
1	Middle	1.06	.98	.79	.25	.34	.21
	Middle	1.17	1.06	1.14	.23	.24	.26
3	Middle	1.38	1.47	1.40	.27	.18	.32
4	Middle	1.39	1.57	1.37	.43	.33	.39
5	Middle	1.56	1.63	1.42	.45	.38	.35
6	Middle	1.65	1.66	1.32	.26	.26	.48
7	Middle	1.60	1.58	1.52	.25	.31	.29
8	Middle	1.52	1.58	1.25	.19	.28	.29
9	Middle	1.42	1.35	1.13	.20	.21	.24
10	Middle	1.11	1.33	1.08	.56	.33	.17
1	Downstream	1.07	1.56	.78	.23	.35	.22
2	Downstream	1.28	1.40	1.12	.27	.32	.24
3	Downstream	1.35	1.32	1.26	.29	.14	.27
4	Downstream	1.38	1.43	1.16	.24	.33	.22
5	Downstream	1.60	1.57	1.40	.20	.48	.30
6	Downstream	1.60	1.54	1.11	.25	.19	.40
7	Downstream	1.59	1.48	1.23	.22	.32	.20
8	Downstream	1.49	1.47	1.40	.21	.23	.25
9	Downstream	1.42	1.31	1.27	.17	.40	.18
10	Downstream	1.17	1.21	1.15	.42	.35	.33

Canal flow measured at HYDROMET gauging station (WESO) = 214.08 cfs
Canal flow estimated with velocity measurements = 176.0 cfs

Approach velocity at bypass channel entrance: 2.08[a] 2.06[a] 2.15[a]

[a] *Measurements collected at 20%, 50%, and 80% of water depth.*

release to the conclusion of trapping was 6.15 hours on Day 1 and 3.62 hours on Day 2. Sampling effort for all test groups averaged 4.2 hours. Percent recapture of test fish groups did not correspond with sampling duration. For some treatment groups released downstream of Diffuser D-3 and at the auxiliary water weir, recapture of groups released earlier was lower than recapture of of groups released later. Capture efficiency of the trap did not account for lower recapture rates of earlier released groups. For Day 1, trap capture efficiency was highest (100%) during the first release, then decreased during the second and third releases (79% and 85%).

Velocity Measurements

Flow through the fish exit gate (Diffuser D-l) at the Three Mile Falls Dam fish ladder was non-uniform. Water velocities measured in front of the fish exit gate ranged from 0.44 fps to 2.03 fps (Table 10). The highest water velocities generally occurred near the water surface and sides of the gate. Mean water velocity at 20% of water depth (1.49 fps) was 104% and 80% higher than the mean velocity at 50% (0.73 fps) and 80% (0.83 fps) of water depth, respectively. Mean water velocity at the left and right (facing downstream) sides of the gate was 1.33 fps and 1.09 fps, respectively. Overall, mean velocity was 38% higher at side Transects 1 and 5 (1.21 fps) compared with middle Transects 2, 3, and 4 (0.88 fps) due to flow obstruction from a midchannel vertical beam. Mean water velocity for sampling locations combined was 1.01 fps. Velocities collected in one location at a l-foot depth upstream of the auxiliary water diffuser averaged 0.54 fps (Table 10).

Table 10. Mean approach velocities (fps) upstream of the fish exit gate (Diffuser D-l) and in front of the auxiliary water diffuser at the Three Mile Falls Dam (east-bank) fish ladder, Umatilla River, 2 May 1994. Transects are numbered in ascending order from left to right (facing downstream). Ladder flow was 137 cfs.

Percentage of water depth	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5
20	1.92	2.03	.84	1.24	1.42
50	1.25	.72	.47	.59	.60
80	.83	.46	1.15	.44	1.26
Mean:	1.33	1.07	.82	.76	1.09

Approach velocity in front of auxiliary water diffuser at 1 ft depth = .54

Total canal flow estimated from mean approach velocities at the four screens at West Extension Canal was 49% lower than estimated canal withdrawal (Table 11). Closure of the bypass channel precluded collection of velocity measurements at the bypass channel entrance. Drum screen approach velocities were fairly uniform among screens (0.11 fps to 0.14 fps) and met criteria for both salmonid fry and fingerlings. Approach velocities were slightly higher at 20% of the submerged screen depth (0.16 fps) than at the 50% or 80% depths (0.10 fps - 0.11 fps). Mean sweep velocities were highest at Screen 1 (0.71 fps) and lowest at Screen 4 (0.51 fps), but fairly uniform among depths (0.60 fps to 0.68 fps).

Video Monitoring

At Furnish Canal, we experienced difficulty observing structures at distances of two feet and greater from the camera due to moderate to high turbidity. Light sensitivity of the camera proved adequate in imaging structures in shadows and at depths of 5 feet to 6 feet. The pipe and camera mount remained stable at the 6-foot depth, at vertical and oblique angles, and at velocities up to 2 fps.

Turbulence and condensation affected image resolution during testing at Three Mile Falls Dam. Fogging on the inside surface of the camera housing window became a problem during testing at the Three Mile Falls Dam east-bank fish ladder. Water velocities near 2 fps at the fish exit gate and associated turbulence made camera imaging difficult, although visibility was improved due to lower turbidity. At some locations, we were able to view images at four feet from the camera. However, the ability to view the entire fish exit gate may not be possible.

Maxwell Canal

Estimated canal flow was within 9% of preliminary HYDROMET readings (Table 12), providing confidence to our measurements. Approach velocity criteria for fry (≤ 0.4 fps) and fingerlings (≤ 0.8 fps) was met at 85% and 100% of the sampling locations, respectively. Highest approach velocity was 0.45 fps at Screen 1 (upstream transect, 50% submerged screen depth). Mean approach velocity was slightly higher for the 50% sampling depth (0.37 fps) compared with the 20% (0.28 fps) and 80% (0.31 fps) sampling depths.

Sweep velocities in front of the drum screens ranged from 0.26 fps to 1.13 fps (Table 12). Sweep velocity was at least twice the approach velocity at screens close to the bypass channel (Screens 1 and 2); whereas, sweep velocity was less than twice the approach velocity at all sampling locations of Screen 3. Mean sweep velocity for Screens 3 (0.41 fps), 2 (0.62 fps), and 1 (1.01 fps) increased with proximity to the bypass channel.

Mean approach velocity at the bypass channel entrance was 2.24 fps (SD = 0.13) during a 9-cfs bypass flow. Approach velocity was slightly higher at 20% (2.28 fps) and 50% (2.36 fps) water depths than at 80% (2.10 fps) water depth (Table 12).

Table **11.** Mean sweep and approach velocities (fps) at the West Extension Canal drum screens, Umatilla River, 7 July **1994.** Drum screens are numbered in ascending order from upstream to downstream. Bypass flow was 0 cfs.

Drum screen no.	Transect	Sweep velocity Percent of screen submergence 20%	 50%	 80%	Approach velocity Percent of screen submergence 20%	 50%	 80%
1	Upstream	.70	.73	.79	.15	.16	.13
2	Upstream	.67	.70	.71	.12	.12	.13
3	Upstream	.65	.71	.70	.24	.10	.09
4	Upstream	.60	.62	.61	.17	.09	.17
1	Middle	.73	.70	.75	.21	.15	.12
2	Middle	.70	.70	.69	.10	.09	.11
3	Middle	.61	.67	.69	.25	.08	.08
4	Middle	.51	.53	.59	.15	.07	.15
1	Downstream	.61	.68	.73	.07	.12	.10
2	Downstream	.57	.65	.66	.21	.06	.07
3	Downstream	.58	.62	.64	.15	.07	.17
4	Downstream	.25	.33	.54	.06	.07	.07

Estimated canal withdrawal = 78 cfs
Canal flow estimated with velocity measurements = 40.1 cfs

Table 12. Mean sweep and approach velocities (fps) at the Maxwell Canal drum screens, Umatilla River, 4 May **1994.** Drum screens are numbered in descending order from upstream to downstream. Bypass flow was 9 cfs.

Drum screen no.	Transect	Sweep velocity Percent of screen submergence			Approach velocity Percent of screen submergence		
		20%	50%	80%	20%	50%	80%
1	Upstream	.92	.91	.96	.27	.45	.35
2	Upstream	.58	.61	.65	.28	.35	.24
3	Upstream	.38	.26	.32	.37	.45	.44
1	Middle	.98	.93	.98	.28	.42	.30
2	Middle	.62	.60	.66	.22	.35	.25
3	Middle	.41	.49	.43	.24	.33	.38
2	Downstream	1.13	1.10	1.11	.28	.32	.32
3	Downstream Downstream	.47	.61	.43	.27	.31	.24

Canal flow measured at HYDROMET gauging station (MAXO) = 34.1 cfs
Canal flow estimated with velocity measurements = 31.2 cfs

Approach velocity at bypass channel entrance: 2.28[a] 2.36[a] 2.10[a]

[a] *Measurements collected at 20%, 50%, and 80% of water depth.*

Facility Monitoring

We primarily surveyed the Feed, Westland, and Furnish canal juvenile fish bypass facilities and associated fish ladders, and the adult passage facility at Three Mile Falls Dam; less effort was expended at West Extension and Maxwell canals. Surveys began 28 October 1993 and ended 9 August 1994 (Table 13). We found few major passage problems for juvenile salmonids during these surveys, but some problems were noteworthy.

At any of the sites surveyed, prolonged periods of precipitation or rapid snowmelt (particularly in early to midspring) were followed by increases in river flow and debris load. The gate at the fish exit at Three Mile Falls Dam, which diverts upstream migrants to an adult holding pond, was severely occluded with debris on 4 March 1994. Approximately two feet of head differential was observed at the diffuser (R. Heine, West Extension Irrigation District, Irrigon, Oregon, personal communication). At Feed Canal, leaf accumulations on drum screens and large debris on trash racks and in the downwell occluded flow. Debris caught in the flap gate at the new wasteway at Westland Canal held the flap gate open for several weeks, affecting the proper operation of the gate.

As the irrigation season progressed, silt deposition increased in front of the screens at all sites. On some visits to Feed and Furnish canals, malfunctioning and non-rotating screens were occluded with silt and algae, impeding flow. Silt deposition was extensive in front of screens at Feed Canal, particularly at the downstream section of each screen (canal dewatered).

At the Westland Ladder in December 1993, low river flow and high gravel piles created numerous braided channels and extremely shallow water conditions upriver from the dam. A gravel pile had also accumulated in front of the adult fish exit and half of the river flow was being diverted through the auxiliary water intake diffuser; debris blockage on the diffuser created a water head differential exceeding one foot. At this point in time, passage conditions appeared hazardous for downstream migrants.

The modified bypass outlet at Westland Canal appeared to work well throughout the season, without gravel aggradation problems. Hydraulics were favorable at the outlet and in the near-river channel for providing good passage conditions.

We observed escapement and mortality of juvenile salmonids near the fish separator at the juvenile pond at Westland Canal on 16 June. Smolts enter the juvenile pond after traveling down the bypass channel and passing through a fish separator located between the juvenile and adult fish ponds. Stimulated by the inflow of water from the fish separator, fish jump and reenter the separator from the juvenile pond; a proportion of these fish manage to clear the separator and fall into the adult pond on the other side of the separator. Numerous live molts were observed in the adult pond and dead molts were observed stranded on ledges adjacent to the fish separator.

Staff gauges were absent upstream and downstream of the drum screens at Furnish and Maxwell canals, inside and outside the fish entrance at the Feed

Table 13. Survey dates at juvenile and adult salmonid passage facilities, Umatilla River, October 1993 - August 1994.

Year	Juvenile passage facilities[a] WEID	WC	FC	MC	FNC	Adult passage facilities[b] TMFD	FCD	WD	SD
	Date					Date			
1993		10/28 11/22 12/7	11/3 11/22 12/6 12/20		11/22	11/3 11/22 11/30 12/7 12/13 12/20	11/3 11/22 12/6 12/20	10/28 11/22 12/7	11/22
1994	5/6 6/16 6/22	1/24 2/14 3/10 4/26 5/24 6/16 7/28 8/9	1/3 1/10 1/18 1/24 2/3 2/14 2/23 3/4 3/10 5/24 6/16 8/9	5/4	4/28 5/24 6/16 6/22 7/28 8/9	1/3 1/10 1/18 1/24 2/23	1/3 1/10 1/18 1/24 2/3 3/4 3/10 4/26 6/16	1/24 2/14 3/10 4/26 5/24 2/14 2/23 3/4 3/10 5/24 6/16	6/22
Total surveys	3	11	16	1	7	15	15	8	2

[a] *WEID = West Extension Irrigation District Canal, WC = Westland Canal, FC = Feed Canal, MC = Maxwell Canal, FNC = Furnish Canal.*
[b] *TMFD = Three Mile Falls Dam, FCD = Feed Canal Dam, WD = Westland Dam, SD = Stanfield Dam.*

Canal Dam fish ladder, at the bypass weir at Feed Canal, and in the bypass downwell at Westland Canal. The improper operation of the automated headgate system at Furnish Canal allowed fluctuations in canal surface water levels. Elevated water levels caused water and fish to unnecessarily pass over the wasteway wall and into shallow water in the wasteway channel leading back to the river. Forebay water elevation rose and fell over a one-hour period with peak levels resulting in 4.5 inches of spill into the wasteway. Fish were only observed passing into the wasteway when spill was greater than two inches.

At Feed Canal, low river flow in early spring 1994 created poor conditions for maintaining a desired headworks elevation of 656 feet and for allowing appropriate flow through the bypass. Low flow over the dam in November 1993 increased the exposure of outmigrating smolts to bird predation. Turbulent flow was observed in the Feed Canal Dam adult fish ladder during both high and low flows, but particularly during high flow. This flow condition resulted after the dam sill height was raised six inches in 1993 to increase the headworks elevation at the canal.

During periods of no or low water withdrawal into the West Extension Canal (when Columbia River exchange pumps were operating), greatly reduced or non-existent flow through the screens produced stagnant water conditions behind and algal accumulations on the screens. In May, three feet of spill over the bypass channel weir resulted in a more favorable, deeper pool depth and less turbulent conditions in the bypass downwell than exists with the standard 25-cfs bypass flow and a 2.5-foot spill. We also noted, as well as trap and haul personnel, that the adjustable weir in the lower bypass did not fully raise to the proper position as specified for 5-cfs-flow operating criteria.

DISCUSSION

Feed Canal Dam and Feed Canal

Injury

We de-emphasized our evaluation of injury associated with the fish bypass facility at Feed Canal primarily because past studies have found negligible injury associated with fish bypass facilities (Hosey & Associates 1988a, 1988b, 1989, 1990, Neitzel et al. 1985, 1987, 1988, 1990a, 1990b, Hayes et al. 1992, Cameron and Knapp 1993, Cameron et al. 1994). In addition, we wanted to expedite testing because previous experience indicated that condition of spring chinook salmon deteriorates rapidly during on-site holding. Although results of the facility injury test at Feed Canal were statistically significant, several factors indicate this injury may not have been facility-caused. Detected injury was moderate and undoubtedly a result of unavoidable, rougher handling of treatment fish during recapture. We recaptured control fish immediately after release when few river-run fish were being collected (midday); whereas, treatment fish were recaptured when large numbers of river-run fish were passing through the facility (evening), making it difficult to minimize stress and injury during collection and handling (Appendix Table C-4).

Yearling spring chinook salmon are able to safely pass through the fish ladder at Feed Canal Dam during high flow operation with no orifice gates installed. However, fish passing through the ladder during low flow operation with orifice gates installed could potentially receive injuries. We were not able to evaluate injury during low flow ladder operation. Large numbers of river-run spring chinook smolts were observed holding in front of the fish ladder exit during high flows. However, during our daytime tests and observations, few smolts were observed entering and moving through the ladder (Appendix Table C-4).

Recovery

Low recapture rates of test fish at Feed Canal were the result of our short-term sampling combined with the diurnal pattern of fish movement. Test and river-run fish movements were greatest during periods of diminishing light as trapping and fish evaluation at the outlet was becoming constrained. As a result, effective recapture was limited to a short time period at the end of our sampling.

Drum Screen Efficiency

Although drum screens were highly efficient at preventing salmonid fingerlings from entering the canal, test conditions were not optimal for potential leakage. Test fish were probably not able to sustain swimming activity against the strong sweeping water velocity present in front of the screens during high canal withdrawals. As a result, most fish were swept past the screens in a short time period. High canal withdrawals are the norm at Feed Canal. Test fish that leaked through the screens most likely accessed the canal through the bottom seals. Side seals and spray foam filler between the screen frames and concrete foundations were in good condition before and after testing. Substantial silt and debris deposits at the base of the screens potentially creates an area of lower water velocity in front of the bottom seals where small fish are able to hide and hold. Silt also contributes to the wear on the seals. Design of drum screen bottom seals, including angle of the seal mount and seal placement on the mount, has improved since the screen facility at Feed Canal was reconstructed (P. Schille, Washington Department of Fish and Wildlife, Yakima, Washington, personal communication). Another recent improvement not incorporated at Feed Canal is the use of screen footings at the base of screens for wedging the screen forward and against the guide walls to eliminate gaps.

Velocity Measurements

Improved methods of measuring water velocities in front of the drum screens at Feed Canal provided more reliable results compared with measurements collected in 1993 (Cameron et al. 1994). Closer agreement between canal flows estimated from our velocity measurements and preliminary HYDROMET readings in 1994 than in 1993 supports this assessment. Increasing the water surface elevation of the screen forebay by six inches in 1994 increased the wetted screen surface area to 80% and helped bring approach velocities down to within criteria. The only potential problem was observed at Screen 1, where the upstream canal wall deflects flow away from the screen (low sweep velocity). Our past observations of small fish holding at this screen location corroborates the low measured velocities. Water current patterns in front of Screen 1 also promoted the deposition of excessive debris and silt immediately downstream of the canal wall.

Although velocities and flows between screens were not uniform, reconfiguration of the horizontal baffle boards cannot produce a fine-tuned velocity control for improved uniformity. Improved velocity control can only be achieved with the use of vertical louvers (S. Rainey, National Marine Fisheries Service, Portland, Oregon, personal communication). The primary purpose of the current baffle board configuration at Feed Canal is for sluicing silt out from under the screens. A change in board configuration to provide gross improvement in velocity uniformity may affect sluicing effectiveness; likewise, a change to enhance sluicing effectiveness could worsen screen velocity uniformity.

As the facility is currently operated, silt readily deposits in front of the screens, especially on the downstream edge of each screen and at Screen 1. Lower sweep velocities at the 80% depth may be a cause or an artifact of these silt piles; such piles probably provide refuge for small fish.

Stanfield Dam and Furnish Canal

Injury

Subyearling fall chinook salmon that passed through the Furnish Canal bypass facility received few injuries. Although injury caused by the headworks canal (CIT) and bypass outlet (BOIT) approached statistical significance, the extent of facility-caused injury was low. Low levels of injury approached statistical significance in these two tests because of low variance in treatment and control injury rates. Injury incurred in the headworks canal was likely a result of releasing disorientated fish into a relatively shallow stretch of canal with high current velocity.

Recovery and Travel Time

Our results indicate that most subyearling fall chinook salmon diverted through the headgates at Furnish Canal will be returned to the river within nine hours. The median travel time of two hours was similar to the 2.9-hour median travel time estimated for subyearling chinook salmon at the Maxwell Canal fish bypass facility (Cameron et al. 1994). As with all travel time estimates, we are unable to assess whether these rates of travel represent a delay in migration without information on inriver migration rates.

Drum Screen Efficiency

Drum screens were nearly 100% efficient at preventing fall chinook salmon fingerlings from entering the canal. High screening efficiency at Furnish

Canal can be attributed to improved designs for drum screen bottom seal mounts and screen footings. In addition, wear on the seals has been minimal during this second season of facility operation. However, additional design features for improving the life and performance of the seals would include screen side bands to minimize side seal wear and the use of screen fasteners compatible with screening material. Electrolysis and corrosion of screen fasteners has been evident and contributes to bottom seal wear with contact during screen rotation (E. Spigler, U.S. Bureau of Reclamation, Yakima, Washington, personal communication).

Velocity Measurements

The lack of close agreement between our calculated flow from velocity measurements and the HYDROMET flow reading suggests that velocities may have been overestimated by about 30%. Overestimation implies that actual approach velocities are probably lower and closer to meeting criteria than what we reported here. Our use of instantaneous readings (at the 80% depth) to determine the predominant direction and angle of flow approaching the screens may have produced some error; with this technique, angle estimation is not as precise. The absence of screen rotation during our measurements could also have affected measurement accuracy. Electromagnetic interference with the screens rotating would have produced highly erratic measurements that forced us to turn the screen motors off.

Westland Dam and Westland Canal

Injury

At the Westland Dam fish ladder, subyearling fall chinook salmon were able to move safely through the passage side of the ladder, but received injury from the auxiliary water system. Injury caused by the auxiliary water system was statistically significant even though injury was relatively moderate. Low variation in treatment and control fish injury rates contributed to the strength of the test resulting in statistical significance. Potential sources of injury in the auxiliary water system are the flow baffles and/or diffusers. Yearling summer steelhead and subyearling fall chinook salmon released immediately upstream of the intake had difficulty achieving proper alignment for intake entry. The improper alignment could either deter fish entry or cause fish injury against the intake rack. Conditions (gravel or debris) that direct river flow toward the auxiliary water intake could result in higher diversion rates of river-run fish through the auxiliary water system. Future underwater video monitoring of fish passage in the auxiliary water system could be used to locate the source of injury.

Trap and haul fish loading procedures at Westland Canal using either a Neilson fish pump or pescalator caused few injuries to (river-run) subyearling chinook salmon. During the evaluation of pump loading, we were able to measure the condition of fish prior to crowding and loading more precisely than similar tests conducted in 1993 (Cameron et al. 1994). Both pump and pescalator loading caused fewer injuries to fish than dip-net loading (Cameron et al. 1994). However, fish are likely to become stressed by the awkward crowding and lengthy time required for loading with the pescalator (Walters et al. 1994). Thus, loading by pump should be the preferred method until pescalator loading can be further evaluated with larger numbers of fish and fish of yearling age.

Recovery

Recovery rates suggest that subyearling fall chinook salmon can move through the fish ladder at Westland Dam within two hours. Test fish appeared to be able to hold in the auxiliary water system for a longer time than in the passage side of the ladder. Low water velocities downstream of flow baffles in the auxiliary water stilling pool are probable holding areas. Shut-down of the auxiliary water system should have negligible effect on juvenile fish passage since fish remaining in the stilling pool will still be able to exit the ladder.

Velocity Measurements

The lack of agreement between our calculated flow from velocity measurements and the HYDROMET flow reading suggests that velocities may have been underestimated by 18%. Underestimation implies that actual approach velocities are probably higher than what we reported here.

Velocity measurements collected in 1993 in front of the drum screens at Westland Canal (Cameron et al. 1994) were undoubtedly inaccurate due to electromagnetic interference from the operating drum screens. We noted that aberrant and negative readings occurred as far as 1.5 feet in front of the screens. We observed a similar pattern at Furnish Canal. Electromagnetic interference has been discovered by other researchers performing similar evaluations (C.S. Abernathy, Battelle, Pacific Northwest Laboratory, Richland, Washington, personal communication).

Imprecise measurements in 1993 at Westland Canal, as well as others, could also have been caused by the particular method we used wherein the unidirectional meter probe was positioned parallel or perpendicular to the screen face to respectively measure sweep and approach velocities. Such a positioning created a "shadow effect" at the probe with non-laminar flows, resulting in poor and erratic readings (W.S. Rainey, National Marine Fisheries Service, Portland, Oregon, personal communication).

Three Mile Falls Dam and West Extension Canal

Injury

Several factors contributed to the difficulty in obtaining conclusive results for the ladder injury test at Three Mile Falls Dam. Test logistics and sampling periods constrained by adult fish passage resulted in low sample sizes and recapture rates, respectively; this affects statistical reliability. Results were also confounded by high trap and handling-caused injury. We experienced the same sampling and logistical constraints in 1993. However, 1993 test results with subyearling fall chinook salmon were the most reliable of all tests due to good recapture rates (Cameron et al. 1994); these tests showed that the lead gate caused statistically significant injury to fish passing through. Injury tests with spring chinook salmon in 1994 suggest modifications to the lead gate may have reduced the injury potential at the gate. More conclusive information will be obtained by monitoring fish passage through the lead gate with underwater video.

Recovery

Low recapture rates of treatment fish released upstream of the lead gate coupled with observations of many fish holding upstream of the lead gate at the conclusion of testing suggest the lead gate may impede downstream movements of fish.

Velocity Measurements

Velocity measurements in front of the fish exit gate and auxiliary water diffuser corroborated the results of ladder injury tests. Injury rates and velocity measurements were highest at the lead gate and lowest at the auxiliary water diffuser. However, more extensive documentation of water velocity in front of the auxiliary water diffuser is needed.

Non-uniform water velocity measured in front of the fish exit gate appeared to be primarily the result of flow deflection around a midchannel I-beam located one foot in front of the gate. The I-beam and wall mounted guides adjacent to the beam appear to have served as stoplog guides prior to the installation of mechanized gates at the fish exit. In the designing of fish ladders, midchannel structures are minimized to reduce potential injury to juvenile fish (W.S. Rainey, National Marine Fisheries Service, Portland, Oregon, personal communication).

Although we attempted to improve velocity reading accuracy by turning off the 110-volt screen motors at West Extension Canal during measurements, accuracy was probably impaired with the use of instantaneous readings to determine the predominant direction of flow approaching the screens at 50% and 80% sampling depths. Erratic currents were also evident due to the closed bypass channel. With the bypass closed and canal headgates partially open, velocities under standard operations could not be measured.

Maxwell Canal

Canal flow estimated by mean approach velocity suggests approach velocities measured in front of the drum screens at Maxwell Canal were reasonably accurate. At 34% of maximum nominal canal- flow, approach velocities met velocity criteria for fingerlings at all locations, and at most locations for fry. However, sweep velocities were low at the upstream screen (Screen 3). Increasing bypass flow is not a viable remedy; sweep velocity would only be slightly increased and bypass channel velocity would become excessive.

Facility Monitoring

In general, the detection of few major passage problems at facilities for juvenile salmonids indicated that operation and maintenance of the facilities is fairly adequate and that the facilities are operating as designed. Efforts should still be expended to guard against acute problems under high flow (and low flow) conditions and during peak outmigrations.

High debris loading on trash racks, screens, and diffusers will increase water velocity through these structures and potentially create conditions that impinge or injure fish. Regular cleaning and maintenance is most critical for the fish exit gate at the Three Mile Falls fish ladder. Previous studies have indicated that fish passing through the fish exit gate are injured and that a substantial proportion of outmigrating smolts use the ladder as a passage route (Cameron and Knapp 1993, Cameron et al. 1994). The fish exit gate has been recently modified to reduce injury and debris accumulation by removal of approximately half the horizontal support bars. Although debris does not accumulate as rapidly on the modified diffuser as compared with the original design (R. Heine, West Extension Irrigation District, Irrigon, Oregon, personal communication), substantial amounts of debris entering the ladder has resulted in severe blockage. Frequent removal of debris throughout the day during periods of high flow and high debris loads may be necessary to avoid debris accumulation and occlusion on this and other structures at facilities along the river.

Another crucial maintenance procedure is the removal of gravel and debris accumulations at the Westland Dam fish ladder. Tests conducted this year indicated fish passing through the auxiliary water portion of the ladder were injured. Debris accumulation on diffusers and baffles in the auxiliary water system will likely worsen passage conditions. In addition, gravel or debris accumulations that deflect river flow toward the intake will probably result in higher fish diversion rates into the auxiliary water system.

Excessive spill into the wasteway at Furnish Canal is a fish passage concern. Fish passing over the wasteway are likely to be injured by the 4.5-foot drop into shallow water (2 - 3 inches depth). The automated headgate system or wasteway sill height should be corrected to ensure spill into the wasteway does not exceed one inch.

Feed Canal Dam was modified in 1993 by the addition of six inches of sill height to provide the head necessary to raise the water surface elevation in the screen forebay six inches. As a consequence, flow through the fish ladder has increased and created very turbulent conditions inside the ladder. Turbulent flow is a concern for both juvenile and adult fish passage. Raising the floor elevation of the ladder may be necessary to meet ladder design specifications (E. Meyer, National Marine Fisheries Service, Portland, Oregon, personal communication).

RECOMMENDATIONS

1. Install staff gauges upstream and downstream of the drum screens at Furnish and Maxwell canals, inside and outside the fish entrance at the Feed Canal Dam fish ladder, and in the bypass downwell at Westland Canal to better regulate flows according to criteria.

2. Continue to operate Feed Canal at a headworks elevation of 656.0 feet to provide an 80% screen submergence for proper screen velocities.

3. Evaluate feasibility of retrofitting drum screens at Feed Canal and Westland Canal with foot and top wedges and an improved design for bottom seal mounts to eliminate gaps.

4. Evaluate potential modification of the fish ladder at Feed Canal to reduce turbulent ladder flow caused by the increased dam height.

5. Correct operation of automated headgates or increase wasteway sill height at Furnish Canal to prevent excessive spill into the wasteway.

6. Add side bands to drum screens at Furnish Canal and Westland Canal to reduce seal wear.

7. Continue regular removal of debris or gravel accumulations at the Westland Dam fish ladder that deflect river flow and juvenile fish toward the auxiliary water intake; maintain all facilities as debris-free as possible.

8. Pumping is the preferred method for loading subyearling fish into transport tanks at Westland Canal; dipnetting should be avoided; and, further testing of the pescalator is suggested.

9. Remove midchannel I-beam and wall mounted guides in front of the lead gate at the Three Mile Falls Dam (east-bank) fish ladder for improved juvenile fish passage.

10. Develop operating criteria for the juvenile fish bypass facility at West Extension Irrigation District Canal to improve fish passage during Phase I water exchange. Develop protocol and procedures for operation of this and other facilities by various agencies for purposes of outmigration monitoring and sampling.

ACKNOWLEDGMENTS

Evaluation activities could not have been successfully completed this year without the support and assistance of numerous individuals from various agencies. From our agency, we very much appreciated the hard work of our field crew: Becky Banghart, Troy Baker, Tracey Bruce, Jill Berry, Doug Neisz, and Brian Riggers. Extra thanks are extended to Doug Neisz for his involvement in field preparations and equipment construction. We thank Rikki Culley, who worked with us through the Apprenticeship in Science and Engineering Program, for her assistance in final field activities and in the preparation of this report. And we appreciated the interest and help of Denise Henderson, a student at Hermiston High School, who worked with us briefly at the end of the field season. We thank Jack Hurst and staff of the Umatilla Hatchery for their generous cooperation in providing test fish. We also appreciated the logistical and technical assistance of Bill Duke from the district office. We thank our advisors, Rich Carmichael and Mary Buckman for their critical review of the manuscript.

We greatly appreciated the assistance of others outside the agency. We welcomed the technical expertise and advise of Steve Rainey and Ed Meyer of the National Marine Fisheries Service Hydraulic Engineering Section. Numerous personnel from the U.S. Bureau of Reclamation provided assistance and support for which we were very grateful. We appreciated the help and cooperation of staff from the West Extension, Hermiston, and Stanfield-Westland irrigation districts. The U.S. Fish and Wildlife Service was again generous in the loan of an office trailer. We thank Jerry Ward and Richard Furhman whose interest in our business resulted in quality equipment for our project.

We especially thank Jay Marcotte and Jerry Bauer of the Bonneville Power Administration for their assistance with project coordination and oversight, and with contracting funds.

REFERENCES

Boyce, R.R. 1986. A comprehensive plan for rehabilitation of anadromous fish stocks in the Umatilla River basin. Final report of Oregon Department of Fish and Wildlife to the Bonneville Power Administration, Portland, Oregon. Contract DE-A179-84P18008.

Cameron, W.A., and S.M. Knapp. 1993. Evaluate the juvenile fish bypass facility in the West Extension Irrigation District Canal at Three Mile Falls Dam and document passaqe of juvenile salmonids through the juvenile fish bypass facility and east-bank adult fish ladder. Measure velocity and develop trap designs at Westland Dam. Pages l-48 *in* S.M. Knapp, editor. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions in the Umatilla River. Annual progress report to Bonneville Power Administration, Portland, Oregon.

Cameron, W.A., S.M. Knapp, and B.P. Schrank. 1994. Evaluation of juvenile salmonid bypass facilities, passage, and trapping and loading procedures at various water diversions in the lower Umatilla River and development of trap designs. Pages l-76 *in* S.M. Knapp, editor. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions in the Umatilla River. Annual progress report to Bonneville Power Administration, Portland, Oregon.

Hayes, M.C., S.M. Knapp, and A.A. Nigro. 1992. Evaluation of the juvenile fish bypass facility in the West Extension Irrigation District Canal at Three Mile Falls Dam and documentation of passage of juvenile salmonids through the bypass facility and east-bank adult fish ladder. Pages 53-103 *in* S.M. Knapp, editor. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions in the Umatilla River. Annual and interim progress report to Bonneville Power Administration, Portland, Oregon.

Hosey and Associates. 1988a. Evaluation of the effectiveness of fish protection facilities, Chandler facility evaluation. Report by Hosey and Associates Engineering Company and Fish Management Consultants for the U.S. Bureau of Reclamation, Yakima, Washington.

Hosey and Associates. 1988b. Evaluation of effectiveness of fish protection facilities, draft report, Columbia facility evaluation. Report by Hosey and Associates Engineering Company and Fish Management Consultants for the U.S. Bureau of Reclamation, Yakima, Washington.

Hosey and Associates. 1989. Evaluation of the effectiveness of fish protection facilities, Roza facility evaluation. Report by Hosey and Associates Engineering Company and Fish Management Consultants for the U.S. Bureau of Reclamation, Yakima, Washington.

Hosey and Associates. 1990. Evaluation of effectiveness of fish protection facilities. Evaluation of Chandler, Columbia, Roza and Easton screening facilities, completion report. Report by Hosey and Associates Engineering Company and Fish Management Consultants for the U.S. Bureau of Reclamation, Yakima, Washington.

Knapp, S.M. 1992. Sampling plan development and preparations for the evaluation of the juvenile fish bypass system in the West Extension Irrigation District Canal at Three Mile Falls Dam and trap designs for future evaluations at Maxwell and Westland dams. Pages 1-52 *in S.M.* Knapp, editor. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions in the Umatilla River. Annual and interim progress report to Bonneville Power Administration, Portland, Oregon.

Knapp, S.M., and D.L. Ward. 1990. Operation and evaluation of the juvenile fish bypass system in the West Extension Irrigation District Canal at Three Mile Falls Dam. Pages 4-32 *in* A.A. Nigro, editor. Evaluation of juvenile fish bypass and adult fish passage facilities at Three Mile Falls Dam, Umatilla River. Annual progress report to Bonneville Power Administration, Portland, Oregon.

Neitzel, D.A., C.S. Abernethy, and E.W. Lusty. 1987. A fisheries evaluation of the Richland and Toppenish/Satus Canal fish screening facilities, spring 1986. Prepared by the Pacific Northwest Laboratory, Richland, Washington, for the Bonneville Power Administration, Portland, Oregon.

Neitzel, D.A., C.S. Abernethy, and E.W. Lusty. 1990a. A fisheries evaluation of the Toppenish Creek, Wapato, and Sunnyside fish screening facilities, spring 1988. Prepared by the Pacific Northwest Laboratory, Richland, Washington, for the Bonneville Power Administration, Portland, Oregon.

Neitzel, D.A., C.S. Abernethy, and G.A. Martenson. 1990b. A fisheries evaluation of the Westside Ditch and Town Canal fish screening facilities, spring 1989. Prepared by the Pacific Northwest Laboratory, Richland, Washington, for the Bonneville Power Administration, Portland, Oregon.

Neitzel, D.A., C.S. Abernethy, E.W. Lusty, and L.A. Prohammer. 1985. A fisheries evaluation of the Sunnyside Canal fish screening facility, spring 1985. Prepared by the Pacific Northwest Laboratory, Richland, Washington, for the Bonneville Power Administration, Portland, Oregon.

Neitzel, D.A., C.S. Abernethy, E.W. Lusty, and S.J. Wampler. 1988. A fisheries evaluation of the Richland and Wapato Canal fish screening facilities, spring 1987. Prepared by the Pacific Northwest Laboratory, Richland, Washington, for the Bonneville Power Administration, Portland, Oregon.

NMFS (National Marine Fisheries Service). 1989. Fish screening criteria. National Marine Fisheries Service, Environmental and Technical Services Division, Portland, Oregon.

NMFS (National Marine Fisheries Service). 1990. Fish passage facilities functional design guidelines and supplemental criteria. National Marine Fisheries Service, Environmental and Technical Services Division, Portland, Oregon.

NPPC (Northwest Power Planning Council). 1987. Columbia River basin fish and wildlife program (as amended). Northwest Power Planning Council, Portland, Oregon.

ODFW (Oregon Department of Fish and Wildlife) and CTUIR (Confederated Tribes of the Umatilla Indian Reservation). 1989a. Columbia Basin system planning, Umatilla Subbasin Plan. Submitted to the Northwest Power Planning Council, Portland, Oregon.

ODFW (Oregon Department of Fish and Wildlife) and CTUIR (Confederated Tribes of the Umatilla Indian Reservation). 1989b. Umatilla hatchery master plan. Prepared for the Northwest Power Planning Council, Portland, Oregon.

SAS Institute Inc. 1990. SAS language: reference, version 6, first edition. Cary, North Carolina.

Starkie, A. 1975. A note on the use of jet inoculator for marking fish. J. Fish. Mgmt. 6:48-49.

Walters, T.R., R.D. Ewing, M.A. Lewis, R.W. Carmichael, and M.L. Keefe. 1994. Evaluation of effects of transporting juvenile salmonids on the Umatilla River at high temperatures. Pages 117-130 *in* S.M. Knapp, editor. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions in the Umatilla River. Annual progress report to Bonneville Power Administration, Portland, Oregon.

APPENDIX A

Juvenile Fish Bypass and Adult Fish Passage
Facility Operating Criteria

Feed Canal Screen Facility (NMFS 26 February 90)

General:

1. Gate G-2 is a closure gate only, and should be open when fish are to be passed.

2. Gate G-3 is used only to drain canal, and should be closed during normal operations. (Residual juveniles holding upstream of screens can be released back to the river through G-3.)

Low Streamflow Operation (no spill):

1. Set head gates and structure gates to maintain canal water surface at EL. 656.0. Canal water surface should not fall below or exceed elevations 655.4 and 656.5 (70% to 90% screen submergence).

2. Set bypass Gate G-l at 0.7 ft. below canal water surface.

Normal Operation (spill):

1. Set head gates and check structure gates to maintain canal water surface at EL. 656.0. Canal water surface should not fall below or exceed elevations 655.4 and 656.5 (70% to 90% screen submergence).

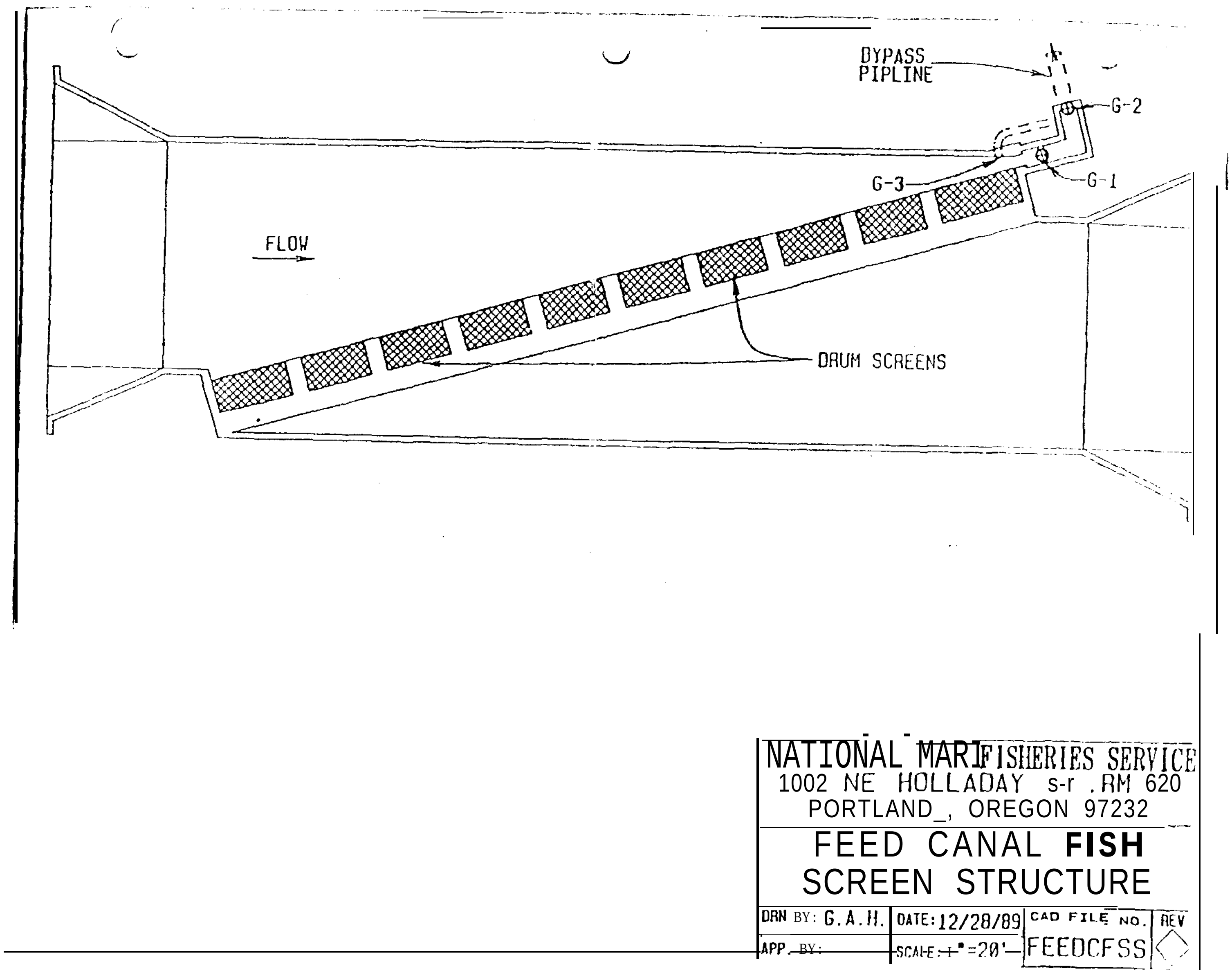
2. Set bypass Gate G-l at 1.5 ft. below canal water surface.

High Water Operation (forebay elevation more than 657.3):

1. Set head gates and check structure gates to maintain canal water surface at EL. 656.5 (90% submergence).

2. Lower bypass Gate G-l to its lowest position.

[Note: If canal water surface is not at or near 90% submergence during high flow periods, bypass flow direction may be reversed.]



Appendix Figure A-l.' Schematic of the Feed Canal screen facility, Umatilla River.

Feed Canal Dam Fish Ladder (NHFS 26 February 90)

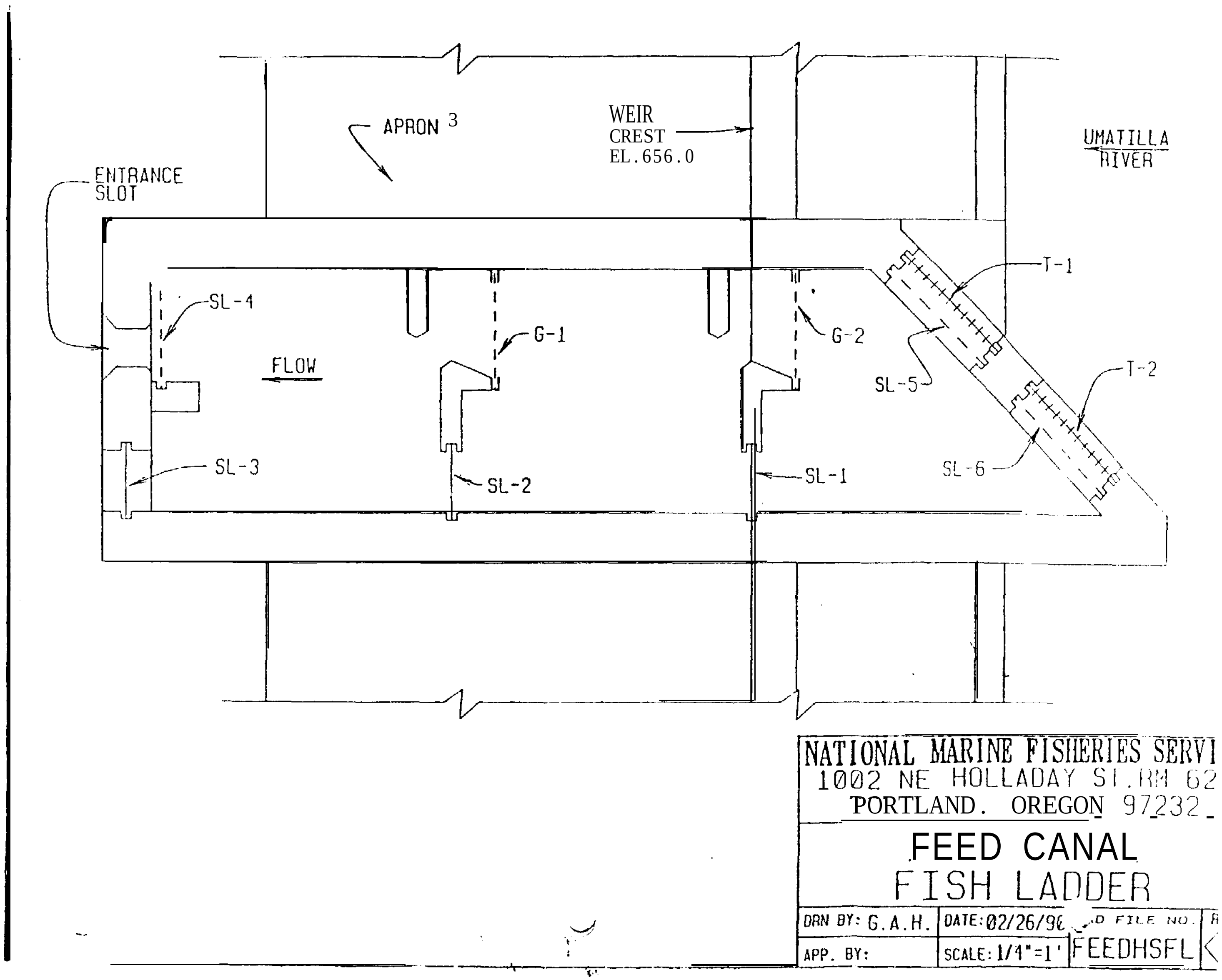
Trashrack Maintenance: Clean Trashracks T-l and T-2. Head differential across each should not exceed 0.3 ft.

Stoplog Operation: Stoplogs SL-1, SL-2, and SL-3 should remain in place, and should not be removed except for sediment sluicing (as required). Stoplogs in SL-4 should never be installed when the fishway is operating. Stoplogs should only be installed in SL-5 and SL-6 when the fishway is to be dewatered.

Low Streamflow Conditions (when there is no spill): Gate G-l and G-2 should be in the down position.

Normal Streamflow Conditions (when there is spill): Gate G-l and G-2 should be in the fully raised position.

[Note: Gates G-l and G-2 should never be positioned in the intermediate position.]



Appendix Figure A-2. Schematic of the Feed Canal Dam adult fish ladder, Umatilla River.

Furnish Canal Screen Facility (NMFS 26 August 93)

General: The design canal water surface level is El. 707.75. The automated head gates should maintain this level through the range of expected adjustments to the downstream check structure.

Trash rack maintenance: Prior to adjustment, inspect and clean as necessary the canal trash rack so the head differential across the rack is 0.2 feet or less.

Normal Streamflow Operation: Adjust the bypass downwell weir gate to 57% open. This corresponds to a design bypass flow of 20 cfs. (To field verify at 57% open, the crest of the weir should be 4 ft, 8.5 inches from the top of concrete).

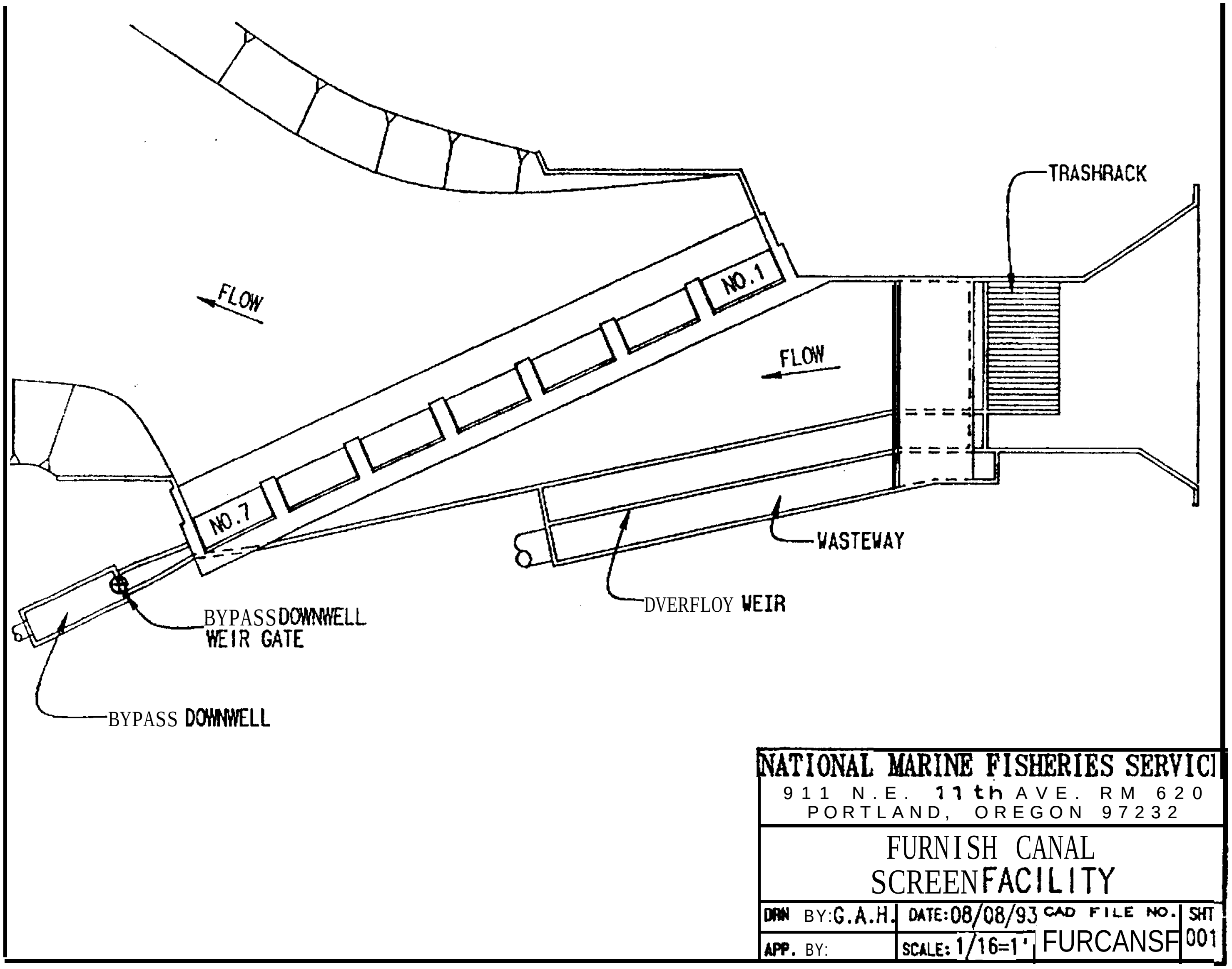
Low Streamflow Operation: A downwell weir gate opening of 50% should correspond to a bypass flow of 15 cfs and the crest should be 4 ft, 4 inches from the top of concrete.

[Notes:]

1. If the canal water surface level is different from the design level (El. 707.75), the automated headgates should adjust. Under no circumstances should the bypass entrance flows be reduced to increase canal flows. This should not be necessary, especially if the canal is properly maintained.

2. Except for temporary flushing of debris, flow through the overflow facilities upstream of the new screen facility should be limited to small amounts (maximum depth over the overflow weir of 0.1 feet) and brief periods. Excessive spill over this overflow weir will likely attract migrating juvenile fish into this area and cause significant delay. If overflow spillage persists, it may be an indication that the wetwell for the head gate sensors has accumulated sediment and should be cleaned. If juvenile fish are observed in the vicinity of the overflow weir, contact fishery agencies personnel for guidance, including recommended operational modifications.

3. If the automated head gate system is operating properly, the water surface in the canal is not expected to fall below El. 707.6 for a significant length of time. If it does, this may be an indication that sediment or weed growth has reduced the hydraulic capacity of the canal upstream. Flashboard risers have been provided to raise the crest of the diversion dam slightly to compensate for this condition.



Appendix Figure A-3. Schematic of the Furnish Canal screen facility, Umatilla River.

Stanfield Dam Fish Ladder (NMFS 19 November 93)

Trash rack maintenance: Prior to flow adjustment, inspect and clean as necessary the fishway exit rack so the head differential across the rack is 0.2 feet or less.

Current Operation: Due to a gravel bar that has formed in front of entrance Gate G-Z, this gate should not be operated for fish passage. Entrance Gate G-l should be full open under all flow conditions until such time as the gravel bar is removed. From observed hydraulic conditions under low and moderate flows, it appears the Gate G-l should effectively pass fish under a wide range of flow conditions.

Future Operation: In the future, fisheries personnel may determine that at extremely high flows it may be desirable to operate entrance Gate G-Z. For entrance Gate G-2 to be fully effective, the gravel bar just downstream should be removed. Once the gravel bar is removed, the following operating criteria should be implemented.

With Dam Flashboards

Low Flow Operation: When tailwater gauge outside the entrance gates reads lower than El. _____ (not determined).

1. Entrance Gate G-l fully open.

2. Entrance Gate G-2 fully close.

High Flow Operation: When tailwater gauge outside the entrance gates reads higher than El. _____ (not determined).

1. Entrance Gate G-2 fully open.

2. Entrance Gate G-l fully close.

Without Dam Flashboards

Low Flow Operation: When tailwater gauge outside the entrance gates reads lower than El. _____ (not determined).

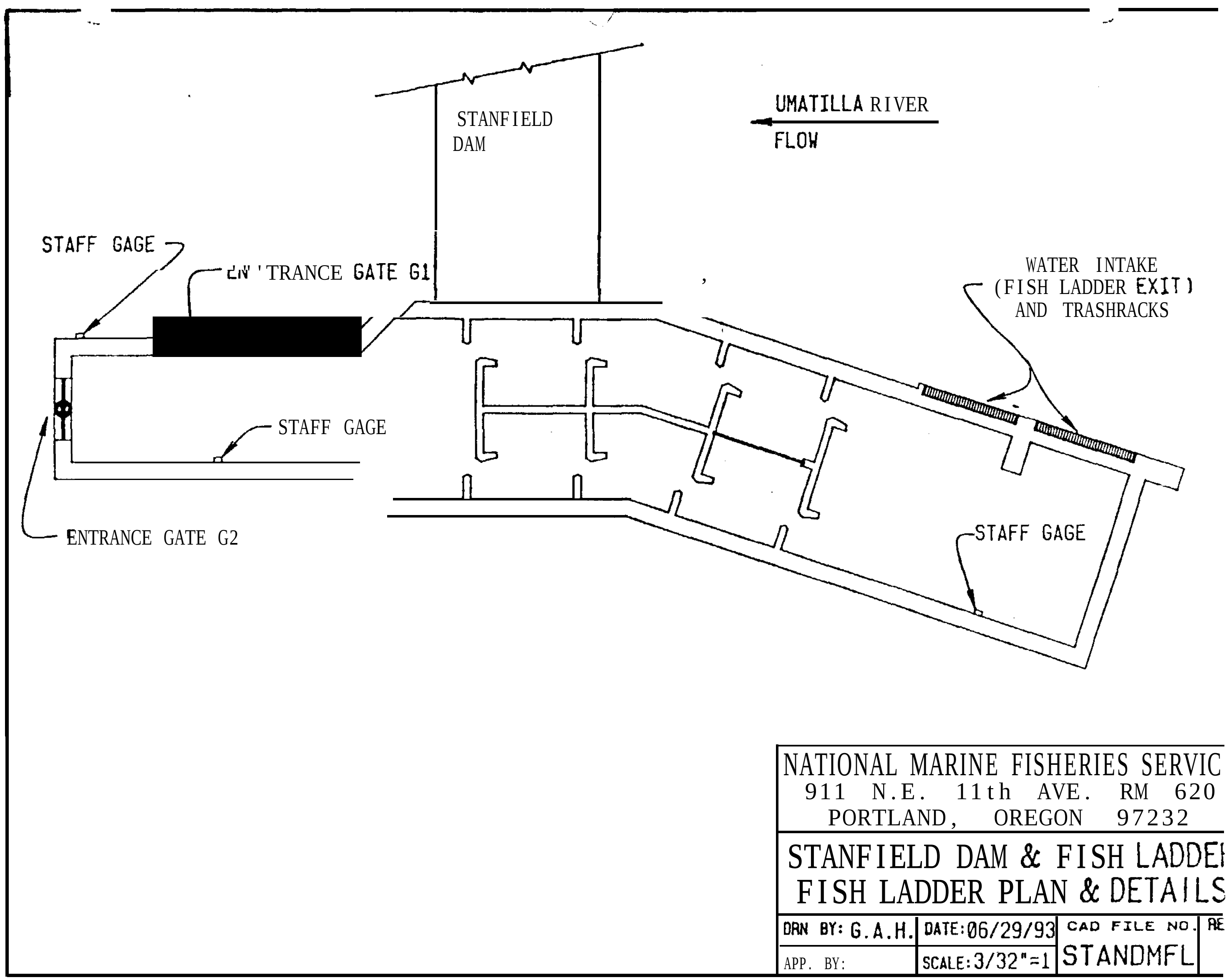
1. Entrance Gate G-l fully open.

2. Entrance Gate G-2 fully close.

High Flow Operation: When tailwater gauge outside the entrance gates reads higher than El. _____ (not determined).

1. Entrance Gate G-2 fully open.

2. Entrance Gate G-l fully close.



Appendix Figure A-4. Schematic of the Stanfield Dam adult fish ladder, Umatilla River.

Westland Dam Fish Ladder (NMFS 7 May 93)

Trash rack and diffuser maintenance: Prior to flow adjustment, inspect and clean as necessary the entrance pool diffuser grating and fishway exit rack so the head differential across each is 0.2 feet or less. Inspect and clean as necessary the auxiliary water trash rack so the head differential across the rack is 0.3 feet or less.

With Dam Flashboards

Low Flow Operation: When tailwater gauge outside the entrance gates reads lower than 638.2.

1. Entrance Gates G-l and G-Z fully open.

2. Entrance Gates G-3 and G-4 closed.

3. Adjust auxiliary water control weir Gate G-5 as necessary to achieve a head differential at the entrances of 1.0 feet (entrance pool water surface 1.0 feet higher than tailwater). At very low river flows, the l.O-foot entrance head will not be maintainable even with the auxiliary weir gate in its lowest position. With the auxiliary weir gate in its lowest position, the entrance head is not expected to fall below 0.5 feet.

4. Occasionally, due to Westland Irrigation District flow diversion requirements, total fishway flow will need to be reduced beyond the operation described by 1, 2 and 3 above. In that event, to further reduce total fishway flow, close entrance Gate G-l and raise auxiliary weir Gate G-5 to throttle flow as required by Westland Irrigation District. When river flow increases sufficiently, resume operation described above.

High Flow Operation: When tailwater gauge outside the entrance gates reads higher than 637.8.

1. Entrance Gates G-3 and G-4 fully open.

2. Entrance Gates G-l and G-2 closed.

3. Adjust auxiliary water control Weir Gate G-5 as necessary to achieve a head differential at the entrances of 1.0 foot (entrance pool water surface 1.0 foot higher than tailwater).

Without Dam Flashboards.

Low Flow Operation: When river flow is adequate to supply the operation of only one entrance gate.

1. Entrance Gate G-2 fully open.

2. Entrance Gates G-l, G-3, G-4 closed.

3. Adjust auxiliary water control Weir Gate G-5 as necessary to achieve a head differential at the entrance of 1.0 foot. (At very low river flow, the 1.0-foot head differential will not be maintainable even with Weir Gate G-5 in the lowest position.)

Medium Flow Operation: When river flow is adequate for two entrance gates to operate with a head differential of 0.5 to 1.0 feet, and with minimal spill over dam crest that does not disrupt attraction flows of upstream entrances (Gates G-l and G-2), as indicated by tailwater elevation below______ (to be determined).

1. Entrance Gates G-2 and G-l opened (Gate G-2 has priority).

2. Entrance Gates G-3 and G-4 closed.

3. Adjust auxiliary water control Weir Gate G-5 as necessary to achieve a head differential at the entrance of 1.0 foot. If auxiliary flow is not adequate to maintain a minimum head differential of at least 0.5 feet when the Weir Gate G-5 is fully lowered, switch to single entrance "Low Flow Operation" described above.

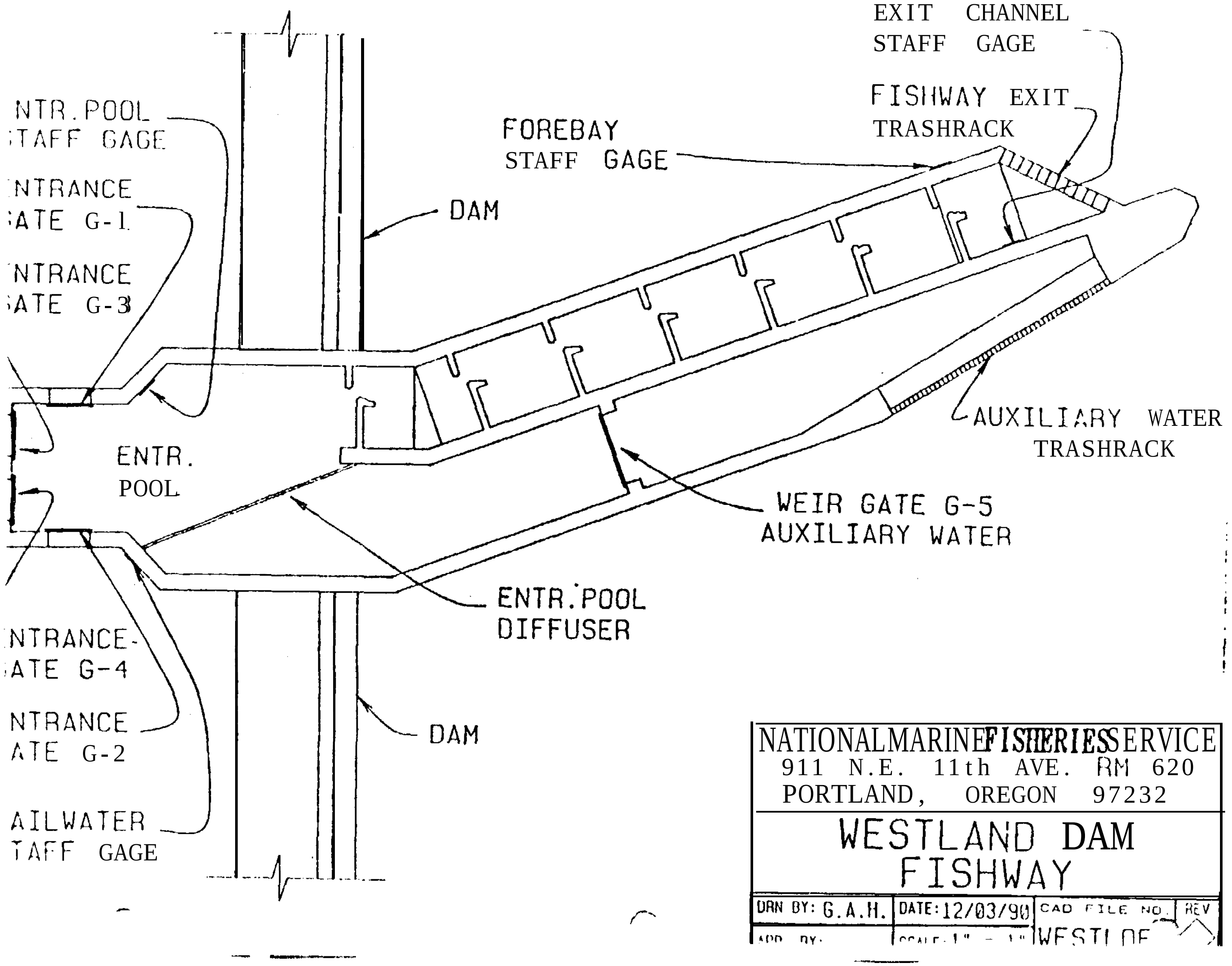
High Flow Operation: When river flow is adequate for two entrance gates to operate with a head differential of 1.0 foot, and with water spilling over the crest of the concrete dam sufficient to prevent effective use of upstream entrances, as indicated by tailwater elevation above ______ (to be determined).

1. Entrance Gates G-4 and G-3 open (Gate G-4 has priority).

2. Entrance Gates G-l and G-2 closed.

3. Adjust auxiliary water control Weir Gate G-5 as necessary to achieve a head differential at the entrance of 1.0 foot. If auxiliary flow is not adequate to maintain a minimum head differential of at least 0.5 feet when the Weir Gate G-5 is fully lowered, close Gate G-3.

[Note: After the flows are adjusted, record date and time, river flow downstream of dam, tailwater elevation, and which entrances are open. This information will assist in refining and amplifying these operation criteria, including establishing appropriate tailwater elevations.]



Appendix Figure A-5. Schematic of the Westland Dam adult fish ladder, Umatilla River.

Three Mile Falls Dam (East-Bank) Adult Passage Facility (NHFS 9 Hay 89)

[Note: This fishway can be operated in the trapping mode (where adult fish are routed through the steep-pass fishway into holding facilities), or passage mode (where fish are allowed to move unimpeded through the fishway).]

Trapping mode: To initiate trapping operations, lower Diffuser D-l and initiate the steep-pass pump operation. Ensure that flow through the holding facility is adequate. (Operating criteria, for the trapping facility to be provided by others.)

Passage mode: To convert to the passage mode, ensure that no fish remain in the adult holding pool, then shutdown the steep-pass pump and lift D-l.

Trash rack and diffuser maintenance: Inspect and clean as necessary the trapping diffuser (D-l), entrance pool diffusers (D-2), counting window crowder diffuser (D-3), and fishway exit trash rack (T-l) so the head differential across each diffuser or rack is 0.2 feet or less. Inspect and clean as necessary the auxiliary water trash racks (T-2) so the differential across the racks is 0.5 feet or less.

Steep-pass pump screen: Inspect and clean as necessary so the head differential across the screens does not exceed 0.5 feet. (This pump only operates during trapping.)

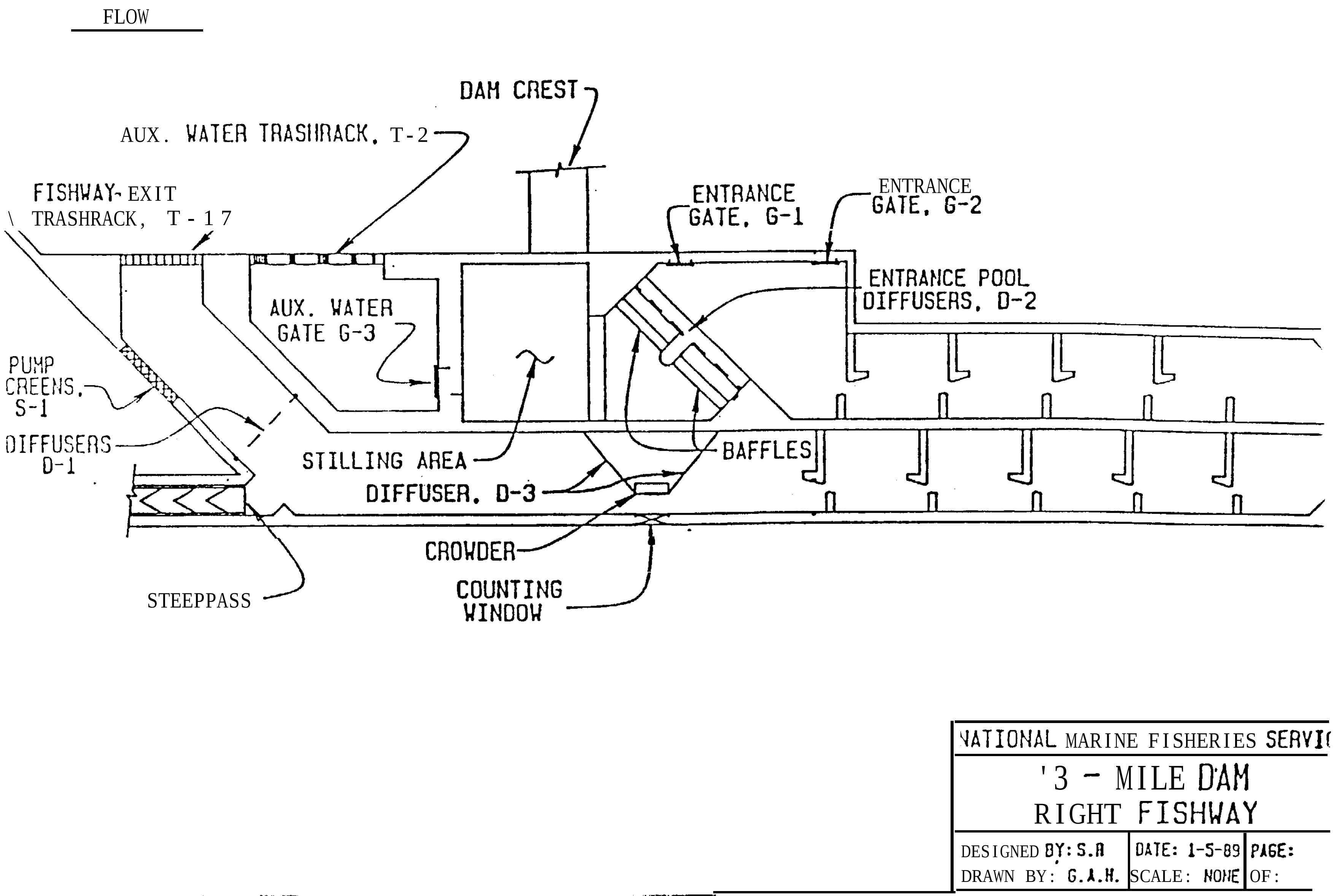
Keep the counting and crowder windows clean. (Brushing this on a daily basis is much easier than letting aquatic growth accumulate, then trying to clean.) Keep staff gages clean and readable.

Entrance gate operation:

1. Entrance Gate G-l should be open during all times that flow past the dam does not exceed 1,600 cfs (forebay elevation 405.2). Entrance Gate G-2 should be closed during this period.

2. During periods when flow past the dam is expected to exceed 1,600 cfs (EL. 405.2) for more than a few days, entrance Gate G-2 should be open. Entrance Gate G-l should be closed during this period.

3. After raking racks, adjust auxiliary water control Gate G-3 as necessary to achieve head differential at the entrance of 1.0-1.5 feet, relative to tailwater.



Appendix Figure A-6. Schematic of the Three Mile Falls Dam east-bank adult fish passage facility, Umatilla River.

APPENDIX B

Experimental Design and Test Fish Releases

Appendix Table B-l. Experimental design of tests conducted at Feed, Furnish, and Westland canals and at Feed Canal, Stanfield, Westland, and Three Mile Falls dams, Umatilla River, spring 1994.

Test[a]	No. tests	T/C[b]	Release dates	Groups per date	No. fish per group	Total no. fish per species	Species[c]
FEED CANAL JUVENILE FISH BYPASS FACILITY							
DSL	1	Thw	3	2	500	3,000	CHF fry
DSL	1	Cfn	3	10	100	3,000	CHF fry
DSL		Cbc	3	2	250	1,500	CHF fry
FIT	1	T		3	100	900	CHS
FIT	1	C	3	3	100	900	CHS
FEED CANAL DAM FISH LADDER							
LIT	1	T	2	3	100	600	CHS
LIT	1	C	2	3	100	600	CHS
FURNISH CANAL JUVENILE FISH BYPASS FACILITY							
DSL	1		3	2	350	2,100	CHF fry
DSL	1	Cfn	3	7	100	2,100	CHF fry
DSL	1	Cbc	3	2	175	1,050	CHF fry
CIT	1	T	3	3	100	900	CHF
SIT	1	T	3	3	100	900	CHF
SIT	1	C	3	3	100	900	CHF
BOIT	1	T	3	3	100	900	CHF
BOIT	1	C	3	3	100	900	CHF
STANFIELD DAM FISH LADDER							
LIT	1	T	2	3	150	900	CHF
LIT	1	C	2	3	100	600	CHF

[a] *DSL = drum screen leakage test, FIT = facility injury test, CIT = canal injury test, SIT = screen injury test, BOIT = outlet injury test, LIT = ladder injury test.*

[b] *T = Treatment, C = Control, hw = headworks, fn = fyke net, bc = bypass channel.*

[c] *CHF = fall chinook salmon, CHS = spring chinook salmon.*

Appendix Table B-l. Continued.

Test[a]	No. tests	T/C[b]	Release dates	Groups per date	No. fish per group	Total no. fish per species	Species
WESTLAND DAM AND CANAL							
LIT	1	T_{f-ex}	1	3	100	300	CHF
LIT	1	T_{aw}	1	3	100	300	CHF
LIT	1	C_{f-en}	1	3	100	300	CHF
LIT	1	T_{f-ex}	1	1	100	100	CHF
LIT	1	T_{aw}	1	1	100	100	CHF
LIT	1	C_{f-en}	1	1	100	100	CHF
LIT	1	T_{f-ex}	1	3	125	375	STS
LIT	1	T_{aw}	1	3	125	375	STS
LIT	1	C_{f-en}	1	3	75	225	STS
T&H	1	T_{pmp}	3[c]	3	100	900	CHF[d]
T&H	1	T_{wd}	3[c]	3	100	900	CHF[d]
T&H	1	C_{pnd}	3[c]	3	100	900	CHF[d]
PES	1	T_{pes}	1[c]	a	100	800	CHF[d]
PES	1	C_{dn}	1[c]	4	100	400	CHF[d]
THREE MILE FALLS DAM (EAST-BANK) FISH LADDER							
LIT	1	T_{ud-1}	1	3	150	450	CHS
LIT	1	T_{dd-3}	1	3	150	450	CHS
LIT	1	T_{aww}	1	3	150	450	CHS
LIT	1	C_{aww}	1	3	100	300	CHS
LIT	1	T_{ud-1}	1	1	150	150	CHS
LIT	1	T_{dd-3}	1	1	150	150	CHS
LIT	1	T_{aww}	1		150	150	CHS
LIT	1	C_{aww}	1	1	100	100	CHS

[a] *LIT = ladder injury test, T&H = trap and haul evaluation, PES = Pescalator evaluation.*
[b] *ud-1 = upstream of Diffuser D-l, dd-3 = downstream of Diffuser D-3, aww = auxiliary water weir, f-ex = fish exit, f-en = fish entrance, aw = auxiliary water system, pmp = pump, cwd = crowd, pnd = pond, pes = Pescalator, dn = dip-net.*
[c] *Collection dates.*
[d] *River-run fall chinook salmon.*

Appendix Table B-2. Hatchery transfer and research liberation information for hatchery-reared test fish used during the juvenile fish passage evaluation, Umatilla River, 1994.

TRANSFERS

Species	Lot	Hatch	Pond	Stock	Slip #	Date	#Rec'd	#/lb	Mark/%
CHS	7592	UM	04B	Carson	72106	3/20/94	2,024	8.8	LV/100
CHS	7592	UM	05A	Carson	72107	3/20/94	2,499	8.5	LV/100
CHS	7592	UM	04A	Carson	72105	3/21/94	2,974	8.4	LV/100
CHS	7594	UM	05B	Carson	72108	3/20/94	2,495	8.1	LV/100
CHF	4593	UM	03A	UM	72110	4/04/94	7,524	171.0	RVBWT/100
STS	9193	UM	M5A	UM	72111	4/11/94	1,699	5.7	AD/100
CHF	4593	UM	03B	UM	72112	4/12/94	5,246	154.3	RVBWT/100
CHF	4593	UM	M3C	UM	72114	5/09/94	5,253	85.0	RVBWT/100
CHF	4593	UM	M3B	UM	72113	5/09/94	5,254	95.0	RVBWT/100

LIBERATIONS

Species	Lot	Hatch	Pond	Stock	Mark/%	Rel Date	(live) # Rel	#/lb	lbs. Rel	Slip #	Rel.Loc.[a]	Morts
CHS	7592	UM	XXX	Carson	LV/100	3/22/94	59	8.8	6.7	72325	RM 29.2	572
CHS	7592	UM	XXX	Carson	LV/100	3/23/94	592	8.8	67.3	73351	RM 29.2	169
CHS	7592	UM	XXX	Carson	LV/100	3/24/94	583	8.5	68.6	73352	RM 29.2	81
CHS	7592	UM	XXX	Carson	LV/100	3/25/94	589	8.5	69.3	73353	RM 29.2	72
CHS	7592	UM	XXX	Carson	LV/100	3/28/94	617	8.4	73.5	73354	RM 29.2	85
CHS	7592	UM	XXX	Carson	LV/100	3/29/94	618	8.4	73.6	73355	RM 29.2	20
CHS	7592	UM	XXX	Carson	LV/100	3/31/94	1,695	8.1	209.3	73356	RM 3.0	39
CHS	7592	UM	XXX	Carson	LV/100	3/31/94	3,419	8.1	422.1	73357	RM 29.2	47
CHS	7592	UM	XXX	Carson	LV/100	4/01/94	639	8.1	78.9	73358	RM 3.0	13
CHS	7592	UM	XXX	Carson	LV/100	4/02/94	79	8.1	9.8	73359	RM 29.2	41
CHF	4593	UM	XXX	UM	RVBWT/100	4/05/94	2,494	171.0	14.6	73360	RM 29.2	1,528
CHF	4593	UM	XXX	UM	RVBWT/100	4/07/94	2,448	171.0	14.3	73361	RM 29.2	97
CHF	4593	UM	XXX	UM	RVBWT/100	4/09/94	2,267	171.0	13.3	73362	RM 29.2	1
STS	9193	UM	XXX	UM	AD/100	4/15/94	325	5.7	57.0	73363	RM 27.3	1
STS	9193	UM	XXX	UM	AD/100	4/16/94	1,407	5.7	246.8	73364	RM 27.3	0
CHF	4593	UM	XXX	UM	RVBWT/100	4/20/94	1,728	154.3	11.2	73365	RM 32.5	88
CHF	4593	UM	XXX	UM	RVBWT/100	4/18/94	1,749	154.3	11.3	73366	RM 32.5	25
CHF	4593	UM	XXX	UM	RVBWT/100	4/22/94	1,748	154.3	11.3	73367	RM 32.5	38

[a] RM 29.2 = Feed Canal Dam juvenile fish bypass and adult fish ladder
RM 3.0 = Three Mile Falls Dam east-bank adult fish ladder.
RM 27.3 = Westland Dam adult fish ladder.
RM 32.5 = Furnish Canal juvenile fish bypass and Stanfield Dam adult fish ladder.

Appendix Table B-2. Continued.

Species	Lot	Hatch	Pond	Stock	Mark/%	Rel Date	(live) # Rel	#/lb	lbs. Rel	Slip #	Rel.Loc.[a]	Morts
CHF	4593	UM	XXX	UM	RVBWT/100	5/10/94	581	95.0	6.1	73368	RM 32.5	26
CHF	4593	UM	XXX	UM	RVBWT/100	5/11/94	578	95.0	6.1	73369	RM 32.5	33
CHF	4593	UM	XXX	UM	RVBWT/100	5/12/94	606	95.0	6.4	73370	RM 32.5	38
CHF	4593	UM	XXX	UM	RVBWT/100	5/12/94	87	95.0	0.9	73371	RM 32.5	0
CHF	4593	UM	XXX	UM	RVBWT/100	5/13/94	740	95.0	7.8	73372	RM 32.5	10
CHF	4593	UM	XXX	UM	RVBWT/100	5/14/94	744	95.0	7.8	73373	RM 32.5	6
CHF	4593	UM	XXX	UM	RVBWT/100	5/17/94	978	85.0	11.5	73374	RM 32.5	40
CHF	4593	UM	XXX	UM	RVBWT/100	5/18/94	975	85.0	11.5	73375	RM 32.5	15
CHF	4593	UM	XXX	UM	RVBWT/100	5/19/94	1080	85.0	12.7	73501	RM 32.5	27
CHF	4593	UM	XXX	UM	RVBWT/100	5/25/94	148	85.0	1.7	73502	RM 27.3	0
CHF	4593	UM	XXX	UM	RVBWT/100	5/26/94	1500	85.0	17.6	73503	RM 27.3	29
CHF	4593	UM	XXX	UM	RVBWT/100	5/27/94	1723	85.0	20.3	73504	RM 27.3	30

Appendix Table B-3. Schedule of test fish releases for 1994 evaluations at the Feed and Furnish canal juvenile fish bypass facilities and the adult fish passage facilities at Three Mile Falls, Feed Canal, Stanfield, and Westland dams, Umatilla River.

Species[a]	Test[b]	Dates	Release no.	Release time	Canal flow (cfs)
FEED CANAL JUVENILE FISH BYPASS FACILITY					
CHS	FIT	3/23, 3/24, 3/25	l-3	1155 - 1520	215 - 242
CHF	DSL	4/5, 4/7, 4/9	l-3	0935 - 1700	208 - 215
FEED CANAL DAM FISH LADDER					
CHS	LIT	3/28, 3/29	l-3	1312 - 1505	--
FURNISH CANAL JUVENILE FISH BYPASS FACILITY					
CHF fry	DSL	4/18, 4/20, 4/22	l-3	0950 - 2000	107 - 117
CHF	BOIT	5/10, 5/11, 5/12	l-3	1132 - 1450	79 - 84
CHF	CIT	5/17, 5/18, 5/19	l-3	1229 - 1754	79 - 84
CHF	SIT	5/17, 5/18, 5/19	l-3	1245 - 1810	79 - 84
STANFIELD DAM FISH LADDER					
CHF	LIT	5/13, 5/14	l-3	1300 - 1500	--
THREE MILE FALLS DAM (EAST-BANK) FISH LADDER					
CHS	LIT	3/31	l-3	1121 - 1450	--
CHS	LIT	4/1	1	1253 - 1348	--
WESTLAND DAM FISH LADDER					
CHF	LIT	5/26	l-3	1516 - 1645	--
CHF	LIT	5/27	1	1454 - 1457	--
STS	LIT	4/16	3	1143 - 1331	--

[a] *CHF = fa77 chinook salmon, CHS = spring chinook salmon, STS = summer steelhead.*

[b] *DSL = drum screen 7eakage test, SIT = screen injury test, BOIT = bypass outlet injury test, CIT = canal injury test, LIT = 7adder injury test.*

APPENDIX C

Ancillary Information from Juvenile Fish Passage Studies

Appendix Table C-l. Retention and quality of acrylic paint marks on yearling spring chinook salmon seven days after marking.

Number marked	Color paint	Mark location[a]	Mark retention (%)	Mark quality[b] good (%)	poor (%)
10	blue	MVB	100	100	0
10	blue	VF	100	100	0
10	biue	AF	100	100	0
10	green	MVB	100	100	0
10	green	VF	100	100	0
10	green	AF	100	100	0
10	red	MVB	100	100	0
10	red	VF	100	100	0
10	red	AF	100	100	0
10	yellow	MVB	100	100	0
10	yellow	VF	100	90	10
10	yellow	AF	100	90	10

[a] *MVB = mid-ventral body surface, VF = base of ventral fin, AF = base of anal fin.*

[b] *good = marks easily identified at a distance of about two feet, poor = marks only identifiable when examined within a distance less than one foot.*

Appendix Table C-2. Mean fork length (mm), and standard deviation, of test fish used in injury evaluations at Feed Canal and Feed Canal Dam, Furnish Canal and Stanfield Dam, Three Mile Falls Dam, and Westland Dam, Umatilla River, spring 1994. All fish originated from the Umatilla Hatchery in Irrigon, Oregon.

Species[a]	Test[b]	Treatment or control	Mean fork length (mm)	Standard deviation	*n*
FEED CANAL JUVENILE FISH BYPASS FACILITY					
CHF fry	DSL	Treatment	64.1	3.8	300
CHF fry	DSL	Cfk	64.6	4.3	300
CHF fry	DSL	Cby	64.0	4.1	300
CHS	FIT	Treatment	166.6	16.0	90
CHS	FIT	Control	165.5	17.1	90
FEED CANAL DAM FISH LADDER					
CHS	LIT	Treatment	167.9	17.7	90
CHS	LIT	Control	168.1	15.6	90
FURNISH CANAL JUVENILE FISH BYPASS FACILITY					
CHF	CIT/SIT	Treatment	80.7	6.2	192
CHF	CIT/SIT	Control	80.2	5.5	80
CHF fry	DSL	Treatment	67.1	3.8	300
CHF fry	DSL	Cfk	66.4	4.4	293
CHF fry	DSL	Cby	65.9	4.2	300
CHF	BOIT	Treatment	78.8	6.4	90
CHF	BOIT	Control	79.5	5.8	90
STANFIELD DAM FISH LADDER					
CHF	LIT	Treatment	79.8	6.0	90
CHF	LIT	Control	80.8	6.0	60

[a] *CHF = fa77 chinook salmon, CHS = spring chinook salmon.*
[b] *DSL = drum screen 7eakage test.*
SIT = screen injury test, CIT = canal injury test.
BOIT = bypass outlet injury test, T&H = trap and hau7 injury evaluation.
LIT = 7adder injury test, FIT = facility injury test.

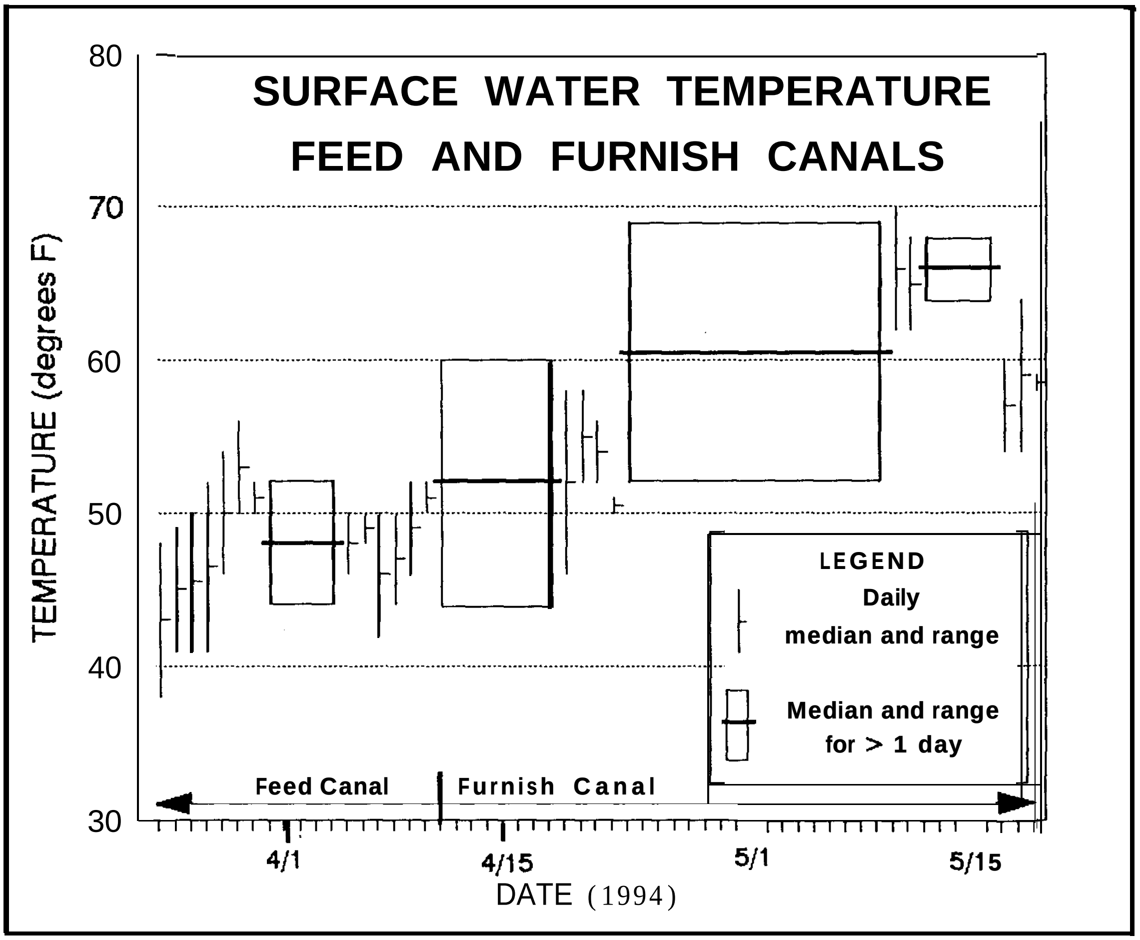
Appendix Table C-Z. Continued.

Species[a]	Test[b]	Treatment or control	Mean fork length (mm)	Standard deviation	n
THREE MILE FALLS DAM (EAST-BANK) ADULT FISH PASSAGE FACILITY					
CHS	LIT	Treatment	163.8	15.7	59
CHS	LIT	Control	163.0	19.7	45
WESTLAND DAM FISH LADDER					
STS	LIT	TRMT-PAS	194.2	21.0	80
STS	LIT	TRMT-ATR	192.2	16.0	81
STS	LIT	Control	192.6	20.0	81
CHF	LIT	TRMT-PAS	83.69	6.4	90
CHF	LIT	TRMT-ATR	86.28	6.1	90
CHF	LIT	Control	86.02	5.5	90
CHF[c]	T&H	TRMT-PMP	94.48	5.9	92
CHF[c]	T&H	TRMT-CWD	92.96	5.2	90
CHF[c]	T&H	Control	94.19	6.8	93

[a] *CHF = fa77 chinook salmon, CHS = spring chinook salmon, STS = summer steelhead.*

[b] *T&H = trap and hau7 injury evaluation. LIT = 7adder injury test.*

[c] *river-run fish.*



Appendix Figure C-1. Median and range of water temperature (^{o}F) recorded at a depth of 0.5 meters in the headworks of Feed Canal and Furnish Canal, Umatilla River, spring 1994.

Appendix Table C-3. Mean sweep and approach velocities (fps) at the Furnish Canal drum screens, Umatilla River, 23 August 1994. Drum screens are numbered in ascending order from upstream to downstream. Bypass flow was 0 cfs.

Drum screen no.	Transect	Sweep velocity Percent of screen submergence			Approach velocity Percent of screen submergence		
		20%	50%	80%	20%	50%	80%
1	Upstream	.72	.73	.74	.30	.29	.27
2	Upstream	.90	.84	.87	.26	.34	.35
3	Upstream	1.01	1.06	1.07	.33	.28	.31
4	Upstream	1.24	1.19	1.16	.31	.26	.23
5	Upstream	1.27	1.12	.95	.32	.30	.22
6	Upstream	1.06	.87	.72	.28	.32	.21
7	Upstream	.66	.59	.55	.32	.34	.22
1	Middle	.68	.74	.78	.30	.34	.25
2	Middle	.90	.87	.83	.21	.25	.34
3	Middle	1.00	1.01	.96	.29	.27	.24
4	Middle	1.17	1.11	1.08	.36	.30	.25
5	Middle	1.19	1.10	.83	.34	.21	.21
6	Middle	.89	.77	.58	.22	.30	.14
7	Middle	.67	.59	.56	.27	.25	.24
1	Downstream	.67	.75	.79	.31	.17	.30
2	Downstream	.89	.85	.91	.25	.26	.21
3	Downstream	1.06	1.06	.98	.24	.25	.17
4	Downstream	1.21	1.07	1.02	.30	.35	.25
5	Downstream	1.09	.85.	.64	.31	.28	.18
6	Downstream	.71	.63	.46	.26	.31	.13
7	Downstream	.54	.44	.20	.21	.17	.07

Canal flow measured at HYDROMET gauging station (FURO) = 77.51 cfs
Canal flow estimated with velocity measurements = 93.50 cfs

Appendix Table C-4. Numbers of river-run juvenile salmonids recaptured while conducting juvenile fish passage tests at Feed Canal and Feed Canal Dam, Furnish Canal and Stanfield Dam, Three Mile Falls Dam, and Westland Dam, Umatilla River, spring 1994.

Date	Time	Trap[a] site	Hatchery fish[b] STS	Hatchery fish[b] CHS	Hatchery fish[b] CHF	Hatchery fish[b] Coho	Wild fish[b] STS	Wild fish[b] CH	Wild fish[b] Coho	Wild fish[b] Fry	Not identifed
FEED CANAL JUVENILE FISH BYPASS FACILITY											
3/23	1400-1652	BO		264	0	0	0	1	0	0	0
3/24	1228-1725	BO	8	1182	0	0	1	1	0	0	0
3/25	1205-1730	BO	0	3271	0	0	0	1	0	0	0
4/5	1100-2359	DW	0	70	449	128	13	4	0	0	997[c]
4/6	0000-2359	DW	3	137	634	1545	19	0	0		69[c]
4/7	0000-1900	DW	0	623	1513	238	31	0	0	8	69[c]
4/7	2000-2130	DW									4000[d]
4/7	2200-2359	DW	0	50	25	1212	3	0	0	0	7[c]
4/8	oooo- 1900	DW	1	222	1396	1953	21	0	1	0	15[c]
4/8	2000-2200	DW									7300[d]
4/8	2300-2359	DW	0	15	4	463					670[c]
4/9	0000-0130	DW									300[c]
4/9	0130-2000	DW	0	513	1834	5929	44	1	1	0	0
4/9	2100-2359	DW									3650[c]
4/10	0000- 1320	DW	1	215	571	2230	6	14	1	0	0
4/10	1320-1400	DW									384[c]
4/10	1400-1415	DW	0	70	144	27	1	2	0	0	0
4/10	1415-1425	DW									480[c]
4/10	1425-1430	DW	0	37	49	10	0	3	0	0	0
FEED CANAL DAM FISH LADDER											
3/28	1312-1502	FE	0	2	5	0	0	0	0	0	0
3/29	1305-1515	FE	0	1	7	0	0	0	0	0	0
FURNISH CANAL JUVENILE FISH BYPASS FACILITY											
4/18	1837-2359	DW	0	1	0	2	0	0	0	0	0
4/19	0000-2359	DW	1	5	2	22	0	0	0	0	0
			2		67	7	0	0	0	0	0
4/21	0000-2359	DW	2	8	105	8	0		1	0	0
4/22	0000-2359	DW		11	63	2	4	8	0	0	0
4/23	0000-1430	DW	0	3	23	0	0	0	0	0	0

[a] BO = bypass outlet, DW = downwell trap, FE = fish entrance.
[b] STS = summer steelhead, CHS = yearling spring chinook salmon, CHF = fa77 chinook salmon, CH = chinook salmon.
[c] Number of fish counted.
[d] Estimated number of fish captured.

Appendix Table C-4. Continued.

Date	Time	Trap[a] site	Hatchery fish[b] STS	Hatchery fish[b] CHS	Hatchery fish[b] CHF	Hatchery fish[b] Coho	Wild fish[b] STS	Wild fish[b] CH	Wild fish[b] Coho	Wild fish[b] Fry	Not identifed
FEED CANAL DAM FISH LADDER											
5/10	1230-1430	BO	369	0	12 15	415	62	0	0	0	
5/11	1315-1550	BO	502	0		1296	201	0	0	0	8
5/12	1125-1330	BO	497	0	6	1108	148			0	0
5/17	1233-2359	DW	14	0	3	1067	9	0	5	19	0
5/18	0000-2359	DW	54	0	4	3247	39	0	7	113	0
5/19	0000-2359	DW	217	0	8	4068	153	0	25	167	60[c]
5/20	0000-1800	DW	526	0		3878	136	0		44	51[c]
STANFEILD DAM FISH LADDER											
5/13	1400-1545	FE	0	0	0	17	0	0	0	0	0
5/14	1245-1515	FE	0	0	0	5	0	0	0	0	0
THREE MILE FALLS DAM (EAST BANK) ADULT FISH PASSAGE FACILITY											
3/31	1123-1741	FE									4304[d]
4/01	1335-1756	FE									5200[d]
WESTLAND DAM FISH LADDER											
5/27	[illegible]	FE	0	0	26 78	0	0	8	0	1 3	0 0

REPORT B

Evaluation of Adult Salmonid Passage at Water Diversions on the Umatilla River and of Their Movement Following Upriver Transport and Assessment of Factors for Homing into the Umatilla River

Prepared by:
Jed Volkman

Confederated Tribes of the Umatilla Indian Reservation

CONTENTS

ABSTRACT

A study of the upstream migration and homing needs of adult salmonids in the Umatilla River was conducted during the 1993-94 return years. Radio telemetry was used to evaluate the movements of adult salmonids in the lower Umatilla River and to determine migrational movements of salmonids following upstream transport. Radio transmitters were placed in 23 summer steelhead (Oncorhvnchus mvkiss), six spring chinook (0. tshawvtscha), three fall chinook, and five coho (0. kisutch) salmon, which were released at Three Mile Falls Dam. An additional 11 summer steelhead and nine spring chinook salmon were tagged, hauled upstream, and released at either Barnhart, Nolin, Thornhollow, or Imeques-C-mem-ini-kern (Fred Grays). On average, summer steelhead required 25 days to successfully migrate from Three Mile Falls Dam to Stanfield Dam. Spring chinook required 12 days. Average passage times for summer steelhead (hours and minutes) at Westland, Feed Canal, and Stanfield dams were 1:30, 48:54, and 1:23 respectively. Spring chinook salmon required 9:14 at Westland, 11:58 at Feed Canal, and 0:44 at Stanfield dams. Miles traveled per day was similar for transported summer steelhead (6.2) and summer steelhead released at Three Mile Falls Dam (6.0). Transported spring chinook salmon moved slower (4.8) than spring chinook released at Three Mile Falls Dam (8.2).

Data related to homing and passage needs of Umatilla River salmonids was investigated in an attempt to maximize homing to the Umatilla River. Straying rates of adult summer steelhead and spring chinook salmon were found to be low while coho and fall chinook salmon straying rates were high in some groups, particularly subyearling smolt releases of fall chinook salmon.

Attraction flows of at least 150 cubic feet per second (cfs) are required to encourage migration of fall chinook and coho salmon into the Umatilla River. Significant numbers of summer steelhead are not seen until flows exceed 500 cfs. Migrational entry for spring chinook salmon is variable with fish entering at flows ranging from 150 to more than 10,000 cfs.

INTRODUCTION

The Umatilla River, located in northeastern Oregon, originates in the Blue Mountains east of Pendleton, Oregon. Below the headwaters, it flows westerly through dry and irrigated farm lands and enters the Columbia River below McNary Dam. In the early 1900's, the lower Umatilla River Basin was developed-for irrigated agriculture. This involved the construction of many permanent and seasonal irrigation diversion dams. Diversion of water, coupled with inadequate or non-existent fish passage facilities at diversion dams, was largely responsible for the total demise of naturally producing salmon in the Umatilla River Basin. Fisheries surveys conducted on the Umatilla River in May, 1944 reported that "although flows were near 500 cubic feet per second (cfs) at Pendleton, the entire flow was diverted prior to entering the Columbia River" (Nielson 1945).

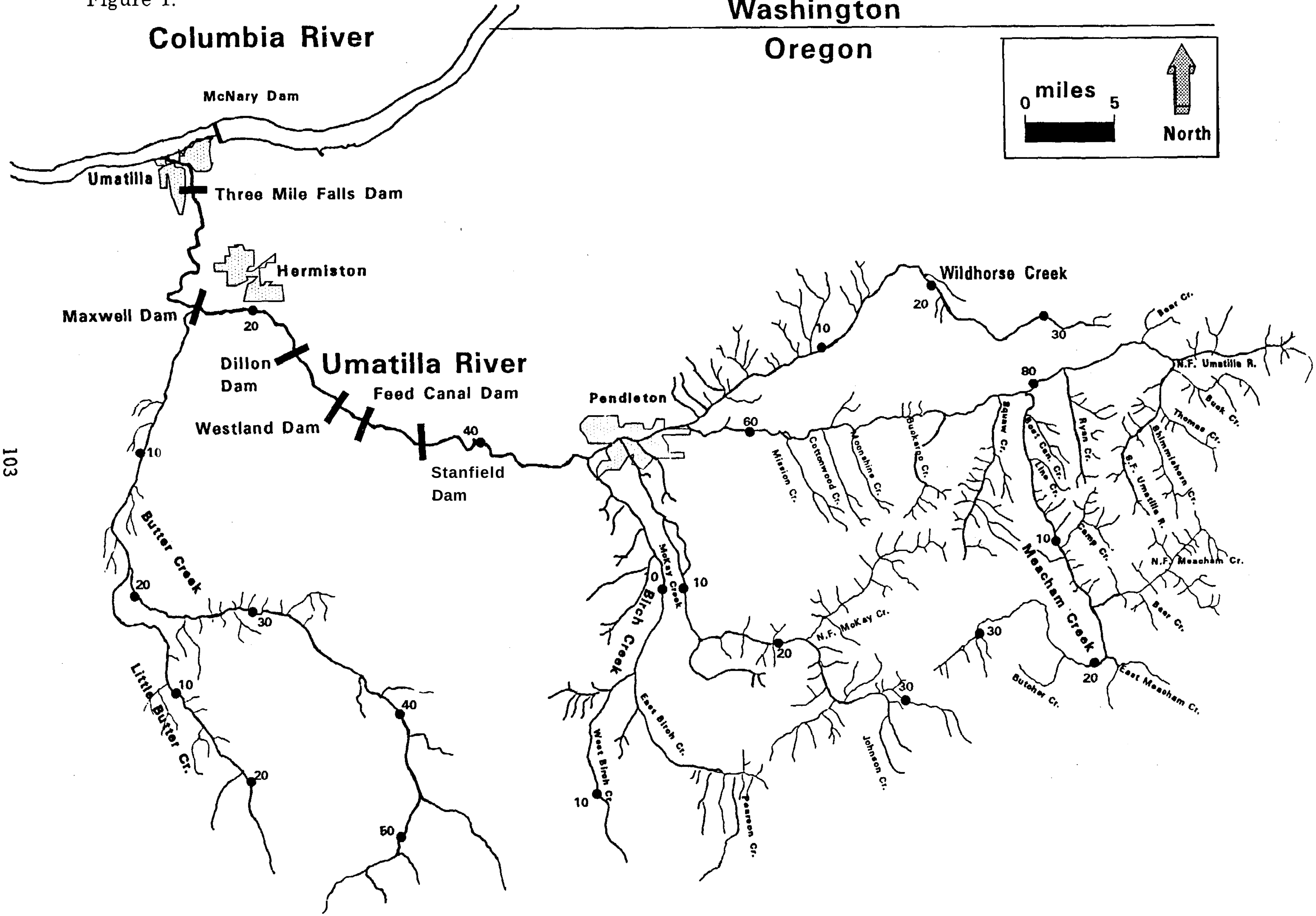
Recently, salmon have been reintroduced in the Umatilla River, and work is being done to improve passage conditions for adult and juvenile anadromous fish. Projects include: instream flow enhancement, juvenile fish screens on irrigation canals, and new or improved fish ladders at irrigation diversion dams. The effectiveness of new fish ladders at irrigation diversion dams is undetermined and the ability of adults to safely migrate to headwater locations is the uncertainty of this study.

The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) initiated a radio telemetry study in 1992 to evaluate adult salmonid passage in the lower Umatilla River. The first year of the project was intended to function as a feasibility study and was thus conducted on a relatively small scale. In 1993, the project was expanded and included an evaluation of adult salmonid movements following upstream transport (trap and haul). Four fixed-site receivers were installed at key locations which generate information regarding passage routes and times through diversion dams at various flows. The primary objectives of this project are: (1) evaluate adult passage past five major diversion dams on the lower Umatilla River, (2) evaluate movements of spring chinook (0. tshawytscha) salmon and summer steelhead (0. mykiss) following upstream transport (trap and haul), and (3) determine migrational timing and flows necessary for homing to the Umatilla River.

STUDY SITE

Radio telemetry work on the Umatilla River encompassed the entire mainstem system and tributaries upstream of Three Mile Falls Dam. Primary emphasis was given to five major irrigation diversion dams. These include Maxwell Dam (river mile 15.2), Dillon Dam (RM 24.6), Westland Dam (RM 27.2), Feed Canal Dam (RM 28.2), and Stanfield Dam (RM 32.4)(Figure 1).

Figure 1.



Washington
Oregon
Columbia River
miles
0
5
North
McNary Dam
Umatilla
Three Mile Falls Dam
Hermiston
Maxwell Dam
Dillon Dam
Umatilla River
Feed Canal Dam
Westland Dam
Stanfield Dam
Pendleton
Wildhorse Creek
Butter Creek
Little Butter Cr.
McKay Creek
Birch Creek
West Birch Cr.
East Birch Cr.
Pearson Cr.
Johnson Cr.
N.F. McKay Cr.
Mission Cr.
Cottonwood Cr.
Moonshine Cr.
Buckaroo Cr.
Squaw Cr.
Bear Cr.
N.F. Umatilla R.
Buck Cr.
Thomas Cr.
Ryan Cr.
Shimmiehorn Cr.
S.F. Umatilla R.
Line Cr.
Camp Cr.
Meacham Creek
N.F. Meacham Cr.
Bear Cr.
Butcher Cr.
East Meacham Cr.

METHODS

Radio Telemetry

This project involves two separate evaluations of adult salmonid movements incorporating the use of radio telemetry. The "passage evaluation" segment evaluates migration of adult salmonids past five major irrigation diversion dams after fish are released at Three Mile Falls Dam (RM 4). The "upstream transport evaluation", determines the movements of salmonids following trap and haul operations.

Fish utilized for the radio telemetry project were captured in the Three Mile Falls Dam adult trapping facility (east-side) and anesthetized with carbon-dioxide. Radio transmitters were inserted into the stomach. After tagging, individually tagged fish were handled in one of two ways: (1) transported upstream by truck and released at either Nolin (RM 33.6), Barnhart (RM 42.2), Thornhollow (RM 73.5), or Imeques-C-mem-ini-kern (Fred Grays, RM 80, upstream transport evaluation), or (2) released in the forebay directly above Three Mile Falls Dam (passage evaluation).

Adult summer steelhead, coho, and spring and fall chinook salmon were radio-tagged for the adult passage evaluation. Only spring chinook salmon and summmer steelhead were included in the upstream transport evaluation. Fish were radio-tagged at various times depending on numbers returning to Three Mile Falls Dam. An attempt was made to tag a representative sample of all fish throughout the adult return period at low, medium, and high river flows. Whenever possible, low water conditions (50-250 cfs) were emphasized because of the prevalence of these conditions in the lower Umatilla River.

Coded transmitters obtained for the study were purchased from Lotek Engineering in Newmarket, Ontario. Radio transmitters were high frequency 150 MHz and varied in size depending on the species being tagged. Summer steelhead and coho salmon received transmitters measuring 4.5 centimeters long and 1.7 centimeters in diameter. Fall and spring chinook salmon transmitters were 8.2 centimeters long and 1.7 centimeters in diameter. All radio transmitters had a minimum operating life of approximately 250 days.

Tagged fish were radio-tracked on a weekly and sometimes daily basis using Lotek SRX 400 radio telemetry receivers. Both mobile and fixed site tracking efforts were employed during the study. Fixed site receivers (with memory capabilities) were installed at Westland, Feed Canal, and Stanfield dams. An additional receiver was installed near the Oregon Department of Fish and Wildlife (ODFW) office in Pendleton, Oregon. Each fixed site receiver (at diversion dams) included two antennas; one underwater antenna in the fish ladder, and one three-element yagi antenna (purchased from Manon Engineering). Receivers were programmed to alternately scan each antenna for six seconds. This arrangement allowed migrational route (fish ladder or over the dam crest) as well as arrival and departure times of individual fish at each diversion dam to be determined. Passage times at diversion dams for individual fish were calculated by comparing first to last recorded times. Passage duration through the diversion areas were determined by comparing the release time at Three Mile Falls Dam to the last recorded time at Stanfield Dam (the uppermost diversion).

Mobile radio tracking involved driving and occasionally walking the portion of the river in which the tagged fish was last located. Once discovered, a more precise location of tagged fish was determined by observing power readings on the receiver in relationship to antenna direction. Extra effort to determine exact location was given when tagged fish were at or near diversion dams.

Migrational movements of radio-tagged summer steelhead and spring chinook salmon in relationship to water temperatures and river flows were included in the telemetry study. Data was provided by Zimmerman and Duke (1994).

CTUIR intended to coincide tagging activities with the arrival of fall chinook and coho salmon at Three Mile Falls Dam. However, budget scheduling prevented equipment purchases and thus tagging activities until late October, 1993. Therefore, no data related to fixed-site receivers (passage routes, passage times, etc.) was generated for coho or fall chinook salmon.

Migrational Timing and Homing Needs

Available data on returning adult coho, fall and spring chinook salmon, and summer steelhead was analyzed in an attempt to understand homing requirements to the Umatilla River. All information related to known Umatilla River origin fish was considered in the search. This included juvenile release data, coded wire-tag recoveries, and radio telemetry data from the University of Idaho Cooperative Fish and Wildlife Research Unit (ICFWRU). Water flow and temperature data was obtained from Zimmerman and Duke 1994.

RESULTS

Radio Telemetry-Passage Evaluation

Fall Chinook Salmon

A total of three fall chinook salmon were radio tagged at Three Mile Falls Dam between October 26 and November 9, 1993. Of these, two successfully migrated over Westland Diversion Dam and one of the two migrated up to, but not past, Feed Canal Dam. The third fish (tagged on October 26, 1993) was found at RM 23.5 on November 4, RM4 (Three Mile Falls Dam) on November 9, and at RM 5.3 on November 29. The tag was recovered at this location on December 8, 1993.

Coho Salmon

Between October 26 and November 5, 1993, a total of five coho salmon were radio tagged at Three Mile Falls Dam. One regurgitated the radio-tag, all others remained below RM 19.3.

Summer Steelhead

A total of 23 summer steelhead were radio-tagged between October 19, 1993 and April 25, 1994. Of these, six (26%) regurgitated the radio tag and two (8.7%) others could not be located shortly after release. Days required to successfully migrate from Three Mile Falls Dam (PM 4) to above Stanfield Dam (PM 32.4) ranged from a high of 120 days to a low of two days with an average of 25 days needed to complete the distance (Table 1). Thirty days were required to complete this section in 1992-93. As expected, migrational behavior was variable and dependant upon entry timing at Three Mile Falls Dam. Fish tagged early in the migration (October-January) typically moved through the system slower than those entering later in the migration (February-April) (Table 1, Appendix A, Figure A-l).

Average migrational passage time (hours and minutes) at Westland, Feed Canal, and Stanfield dams were 1:30, 48:54, and 1:23 respectively (Appendix A, Figure A-2). Percent of fish migrating through the ladder at each diversion was 50% at Feed Canal, 53% at Westland, and 14% at Stanfield (Table 2). Average migrational passage time (in hours and minutes) between Westland and Feed Canal diversion dams (a distance of one mile) was 5:37. Between Feed Canal and Stanfield dams (4.2 miles) required 33:00 (Figure 2).

Migrational delays in relationship to flows were not observed at either Westland or Stanfield dams. Flows encountered during adult passage at these dams ranged from 122 to 2,850 cfs. Migrational delays were documented, however, at Feed Canal Dam at flows ranging from 400 to 1,200 cfs (Table 2, Appendix A, Figures A-3 and A-4).

Similar to findings in 1992-93, delays related to water temperatures were observed at or below 42 degrees fahrenheit. Examples can be seen at both Westland (channel 7 code 7), and Stanfield (channel 7 code 4) diversion dams (Table 2). In both instances,-the fish generating the longest passage time encountered the coldest water temperature.

Spring Chinook Salmon

Between April 14 and April 29, 1994 a total of six spring chinook salmon were radio tagged at Three Mile Falls Dam and five provided passage data. One regurgitated the radio tag. Average time needed to migrate from the release site to above Stanfield Dam was 12 days (Table 3). On average, 11 days were required to complete this distance in 1993. Average passage times at Westland, Feed Canal,

Table 1. Summer Steelhead release dates and days required to successfully migrate to Stanfield Dam (RM 32.4). Umatilla River Passage Evaluation, 1993-94.

Rel. Date	Ch/Code	Stanfield Date	Days to Stanfield	H/W	M/F
10/19/94	7/01	4/2/94	120	w	f
12/7/94	7/03	1/15/94	39	h	f
12/13/94	7/04	1/10/94	28	h	f
1/7/94	7/05	1/13/94	6	w	m
1/10/94	7/06	3/11/94	60	w	m
1/12/94	7/07	3/5/94	52	h	f
3/11/94	7/13	3/15/94	4	h	f
3/11/94	7/14	3/27/94	16	h	f
3/24/94	7/17	3/30/94	6	h	f
3/28/94	7/18	4/21/94	24	h	f
4/4/94	7/23	4/7/94	3	h	f
4/8/94	7/25	4/13/94	5	w	f
4/11/94	7/26	4/17/94	6	h	f
4/14/94	7/27	4/17/94	3	w	m
4/25/94	7/10	4/27/94	2	w	f
			Avg. 25 days		

File name: sts2s3

Table 2. Summer steelhead migrational timing, passage route, flows (cfs), and temperatures (F) at Westland, Feed, and Stanfield Diversion Dams. Umatilla River 1993-94.

First Date	First Time	Ch/Code	Site	Last Date	Last Time	Route	Ladder Duration	Passage Time	Range of Flows (cfs)	Mean Temps(F)
Westland										
3/29/94	2015	7/1	1	3/29/94	2035	1	:05	:20	122	49
1/12/94	658	7/3	1	01/12/94	809	1	:03	1:11	667	44
1/8/94	2155	7/4	1	01/8/94	2245	2		:50	807	43
1/12/94	1718	7/5	1	01/12/94	1751	2		:33	667	44
3110194	1202	7/6	1	03/10/94	1203	2		:01	955	44
2/27/94	2029	7/7	1	02/28/94	1055	1	:06	14:26	148-350	42
4/26/94	2033	7/10	1	4/26/94	2049	1	:02	:16	331	55
3113194	2325	7/13	1	03/13/94	2339	2		:14	754	45
3/17/94	2134	7/14	1	3/17/94	2219	2		:45	1370	45
3/30/94	233	7/17	1	3/30/94	238	1	:02	:05	195	50
3/31/94	1930	7/18	1	3/31/94	2216	2		2:46	364	50
4/6/94	1238	7/23	1	4/6/94	1245	1	:04	:07	429	49
4111194	511	7/25	1	4/11/94	616	2		1:05	547	50
4/14/94	2013	7/26	1	4/14/94	2020	2		:07	478	49
4/16/94	651	7/27	1	4/16/94	656	1	:02?	:05	416	52
1/18/94	1911	20/13	1	01/18/94	2020	1	:06	1:09	631	43
						50%	avg. time	01:30		
Feed Canal										
3/30/94	117	7/1	2	4/1/94	1511	1		61:54	489-716	49
1/12/94	1753	7/3	2	01/13/94	1308	2		19:15	624-998	44
1/9/94	1414	7/4	2	01/9/94	1812	1	:09	3:58	450	43
1112194	2108	7/5	2	01/12/94	2137	1	:04?	:29	624	44
3/10/94	1524	7/6	2	03/10/94	1636	2		1:12	656	44
2/28/94	1404	7/7	2	03/3/94	1240	2		70:36	548-3101	43
4126194	2227	7/10	2	4/27/94	230	2		4:03	569-591	55
3/14/94	236	7/13	2	3/14/94	2250	1	:08	20:14	629	46
3118194	0059	7/14	2	3/19/94	0051	2		23:52	703-787	45
3/30/94	405	7/17	2	3/30/94	707	1	?	3:02	489	50
4/1/94	146	7/18	2	4/20/94	1805	2		472:19	654-1063	50
4/6/94	1425	7/23	2	4/6/94	1557	1	:04	1:32	659	49
4/11/94	1859	7/25	2	4/12/94	1609	1	:05	21:10	755-757	50
4115194	1016	7/26	2	4/16/94	1455	2		28:39	634-667	51
4116194	1019	7/27	2	4/16/94	1141	1	:03	1:22	667	52
						53%	avg. time	48:54		
Stanfield										
4/2/94	1449	7/1	3	4/2/94	1506	2		:17	1033	51
1/15/94	1214	7/3	3	01/15/94	1249	2		:35	1380	45
1/10/94	817	7/4	3	01/10/94	1906	2		10:49	689	43
1/13/94	1102	7/5	3	01/13/94	1153	2		:51	1220	44
3/11/94	1727	716	3	03/11/94	1757	2		:30	862	45
3/5/94	1345	7/7	3	03/5/94	1428	2		:43	2850	44
4127194	1601	7/10	3	4/27/94	1613	2		:12	569	54
3/15/94	1222	7113	3	3/15/94	1259	2		:37	994	48
3127194	2331	7/14	3	3/27/94	2350	2		:19	536	47
3/30/94	1850	7/17	3	3/30/94	1906	2		:16	727	50
4121194	0017	7/18	3	4/21/94	0033	2		:16	1091	56
4/7/94	00:06	7/23	3	4/7/94	0030	1	:08	:24	916	48
4/17/94	334	7/26	3	4/17/94	358	1	:11	:24	893	53
4/1 6194	2107	7/27	3	4/17/94	0022	2		3:15	779-893	53
						14%	avg. time	01:23		
ODFW										
4/16/94	1525	7/1	4	4/16/94	1539					
1125194	2146	7/3	4	01/25/94	2208					
1/16/94	1632	7/4	4	01/16/94	1711					
1/25/94	153	7/5	4	01/25/94	206					
3/28/94	2230	7/6	4	3/28/94	2240					
3/12/94 •	[illegible]	7/7	4	3/12/94	***					
3/6/94	614	7/8	4	03/6/94	632					
3/13/94	329	7/10	4	03/13/94	337					
4/30/94*	0035	7/10	4	4/30/94	0041					
3/13/94	2047	7/12	4	03/13/94	2059					
3/26/94	432	7/13	4	3/26/94	443					
3/31/94	0025	7/14	4	3/31/94	0038					
3/24/94	241	7/15	4	3/24/94	257					
3/24/94	1336	7/16	4	3/24/94	1347					
4/2/94	253	7/17	4	4/2/94	303					
4122194	2312	7/18	4	4/22/94	2322					
412194	1858	7/21	4	4/2/94	1905					
4/9/94	625	7/23	4	4/9/94	635					
4/16/94	2248	7/25	4	4/16/94	2258					
5/2/94	2200	7/26	4	5/2/94	2201					
4/18/94	1958	7/27	4	4/18/94	2001					

• ** -estimated passage date
• – retagged
route 2 = jump over crest, route 1 = fish ladder
site 1 westland, site 2 feed, site 3 stanfield, site 4 ODFW
filename: quart

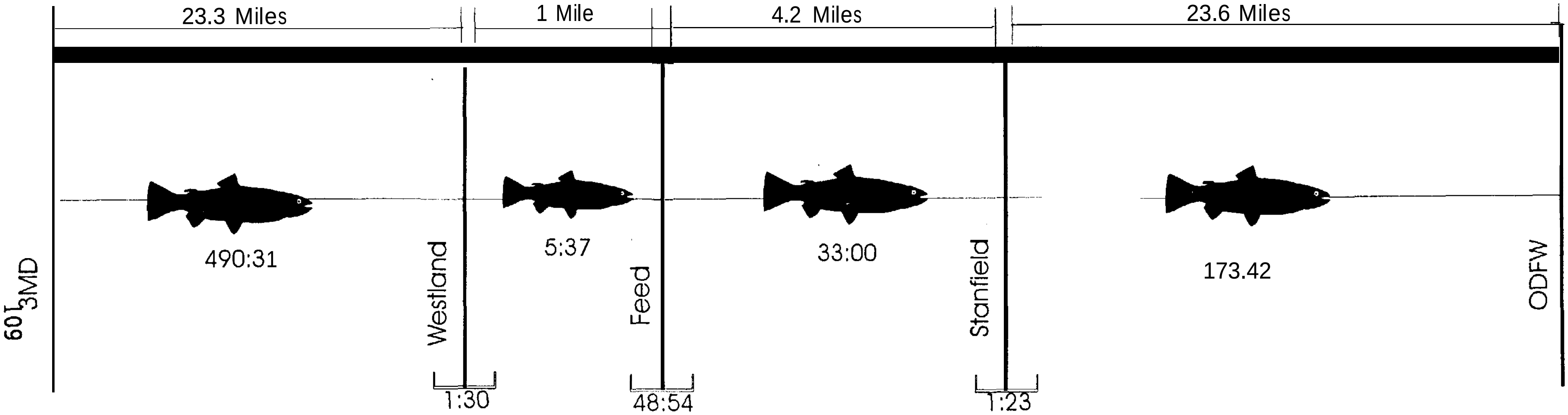


Figure 2. Radio telemetry data depicting average migrational times (hours and minutes) for Summer Steelhead between dams versus passage times over dams, Umatilla River 1993-l 994.

and Stanfield dams were 09:14, 11:58, and 00:44 respectively. Sixty percent of the fish chose to use the fish ladder at Westland, 20% at Feed Canal, and 25% at Stanfield (Table 4).

Table 3. Spring Chinook Salmon release dates and days required to successfully migrate to Stanfield Dam (RM 32.4). Umatilla River Passage Evaluation, 1993-94.

Release Date	Channel/Code	Stanfield Date	Days to Stanfield
4/14/94	13/14	4/20/94	6
4/25/94	13/15	5/4/94	9
4/26/94	13/16	5/9/94	[illegible]
4/27/94	13/17	5/6/94	9
4/29/94	13/18	5/23/94	24
			Avg: 12 days

At Westland Dam, migrational passage time increased as flows reduced. Only five fish provided data at this structure and four of the five demonstrated delayed migration at flows less than 200 cfs. Water temperatures during this period ranged from 58 to 66 degrees fahrenheit.

Passage data collected at Feed Canal Dam (Table 4) occurred over a large range of flows (330 to 1,221 cfs) and did not suggest that a particular flow level was responsible. for delay. Water temperatures during migrational passage ranged from 57 to 66 degrees fahrenheit.

Radio Telemetry-Upstream Transport Evaluation

Summer Steelhead

A total of 11 summer steelhead were radio-tagged between January 20 and April 19, 1994 as part of the upstream transport evaluation. Three (27%) regurgitated the radio tag. The remaining eight fish demonstrated positive upstream migration following release at either Nolin (PM 33.6) or Barnhart (RM 42.2). Migrational rates were similar through the same section of river for summer steelhead transported upstream versus those released at Three Mile Falls Dam. On average, fish released at Three Mile Falls Dam traveled at a rate of 6.0 miles per day between Stanfield Dam and ODFW (Table 5). By comparison, fish hauled upstream traveled an average of 6.2 miles per day between the release site (Barnhart or Nolin) and ODFW (Table 6).

Table 4. Spring chinook salmon migrational timing, passage route, passage time, flows (cfs), and temperatures (F) a Westland, Feed Canal, and Stanfield diversion dams, Umatilla River Passage Evaluation 1993-94.

First Date	First Time	Ch/Code	Site	Last Date	Last Time	Route	Lad&r Duration	Passage Time	Range of Flows (cfs)	Mea Temp
Westland										
4/19/94	634	13/14	1	4/19/94	705	1	:08	:31	830	
4/30/94	421	13/15	1	4/30/94	2118	1	:09	16:57	181	
5/7/94	1344	13/16	1	5/7/94	2028	2		6:44	120	
5/5/94	554	13/17	1	5/5/94	1839	2		12:45	148	
5/8/94	208	13/18	1	5/22/94	1217	1		346:09*	7-2070	
						60%	avg. time	9:14		
Feed Canal										
4/19/94	833	13/14	2	4/19/94	1448	2		6:15	1063	
5/1/94	2229	13/15	2	5/3/94	0022	2		25:53	346-410	
5/7/94	2320	13/16	2	5/8/94	553	1	:09	6:33	347-358	
5/5/94	2052	13/17	2	5/5/94	2129	2		:37	385	
5/22/94	1456	13/18	2	5/23/94	1131	2		20:35	1100-1563	
						20%	avg. time	11:58		
Stanfield										
4/20/94	950	13/14	3	4/20/94	1020	2		:30	1097	
5/4/94	0024	13/15	3	5/4/94	116	2		:52	344	
5/9/94	***	13/16	3	5/9/94	***				330	
5/6/94	349	13/17	3	5/6/94	441	1	:12	:52	372	
5/23/94	1634	13/18	3	5/23/94	1739	2		:65	1221	
						25%	avg. time	:44		
ODFW										
4/24/94	734	13/14	4	4/24/94	748					
5/16/94	119	13/15	4	5/16/94	152					
5/13/94	0009	13/16	4	5/13/94	0030					
5/8/94	2203	13/17	4	5/8/94	2209					
5/25/94	1706	13/18	4	5/25/94	1713					
5/5/94	2301	13/21	4	5/5/94	2309					
5/10/94	328	13/22	4	5/10/94	350					
5/12/94	2303	13/44	4	5/12/94	2310					

*** -- estimated passage date
* -- not included in average passage time
Route 2 = jump over crest, Route 1 = fish ladder
Site 1 Westland, Site 2 Feed, Site 3 Stanfield, Site 4 ODFW
Temps generated at Maxwell Dam RM 15.2
file name: chssites

Table 5. Migration days required and miles moved per day between Stanfield Dam (site 3) and ODFW (site 4). Umatilla River summer steelhead Passage Evaluation, 1993-94.

C h/Code	Rel. Site	Site 3. Date	Site 4. Date	Days	miles/day
7/1	3MD	-- 4/2/94	4/16/94	14	1.7
7/3	3MD	1/15/94	1/25/94	10.4	2.3
7/4	3MD	1/10/94	1/16/94	5.9	4
7/5	3MD	I/I 3/94	I/25/94	11.6	2
7/6	3MD	3/11/94	3/28/94	17.2	1.4
7/7	3MD	3/5/94	3/12/94*	7	3.4
7/13	3MD	3/15/94	3/26/94	10.6	2.2
7/14	3MD	3/27/94	3/31/94	3	7.9
7/17	3MD	3/30/94	4/2/94	2.3	10.3
7/18	3MD	4/21/94	4/22/94	1.9	12.4
7/23	3MD	4/7/94	4/9/94	2.2	10.7
7/25	3MD	4/13/94*	4/16/94	3.5	6.7
7/26	3MD	4/17/94	5/2/94	15.8	1.5
7/27	3MD	4/17/94	4/19/94	1.8	13.1
7/10	3MD	4/27/94	4/30/94	2.3	10.3
					avg. 6.0

Table 6. Migration days required and miles moved per day between release site and ODFW (site 4). Umatilla River summer steelhead Upstream Transport Evaluation, 1993-94.

Ch/Code	Rel. Site	Rel. Date	Site 4 Date	Days to Site 4	miles/day
7/8	Barn hart	2/28/94	3/6/94	5.8	2.4
7/10	Nolin	3/9/94	3/13/94	3.7	6.1
7/12	Barn hart	3/10/94	3/13/94	3.4	4.1
7/15	Nolin	3/14/94	3/24/94	9.6	2.3
7/16	Barn hart	3/22/94	3/24/94	2.1	6.6
7/21	Nolin	3/31/94	4/2/94	2.3	9.7
7/28	Barn hart	4/19/94	4/20/94*	1.1	12.5
					avg. 6.2

*-estimated passage date
file name: 9394sts

Spring Chinook Salmon

Beginning on May 2 and concluding on May 26, 1994 a total of nine spring chinook salmon were radio-tagged at Three Mile Falls Dam and released at either Barnhart, Thornhollow (RM 73.5), or Imeques-C-mem-ini-kern (RM 80). Of these, one regurgitated the radio tag.

Like summer steelhead, all spring chinook salmon demonstrated upstream movement following release. Average migrational rate between Barnhart and ODFW was 4.8 miles per day for fish trapped and hauled (Table 7). This compares to an average of 8.2 miles per day between Stanfield Dam and ODFW for spring chinook salmon released at Three Mile Falls Dam (Table 8).

Migrational Timing and Homing Needs

Fall Chinook Salmon

Coded-wire tag data indicates that Umatilla River fall chinook salmon first enter the John Day Pool during the period August 24 to 30 with peak migration occurring during the first two weeks of September (Kissner 1992, Wagner 1990). This is consistent with mainstem passage data for McNary Dam shown in Table 9. Clearly, Umatilla River origin fall chinook salmon are above or below the mouth of the Umatilla River in late August and early September. Yet, entry timing for fall chinook salmon at Three Mile Falls Dam varies from early October to late December.

Entry dates for fall chinook salmon at Three Mile Falls Dam during the last three return years do not suggest that temperatures are delaying entry. Attraction flows below Three Mile Falls Dam appear to have a more profound effect. In 1991, 1992, and 1993 significant numbers of fall chinook began entering the Umatilla River when flows exceeded 150 cfs (Appendix A, Figures A-5 to A-7).

Homing rates for Umatilla River fall chinook salmon during the last four return years have ranged from a low of 28.4% in 1992 to a high of 60.4% in 1990. Relative to peak migration over McNary Dam, average attraction flows exiting the Umatilla River for the period of September 1-15 (1990-1993) ranged from a low of 1.5 cfs in 1992 to a high of 78 cfs in 1993 (Table 10).

Table 7. Migration days required and miles moved per day between release site and ODFW (site 4). Umatilla River spring chinook salmon Upstream Transport Evaluation, 1993–94.

Ch/Code	Rel. Site	Rel. Date	Site 4 Date	Days to Site 4	miles/day
13/21	Barn hart	5/2/94	5/5/94	3.5	4
13/22	Barnhart	5/6/94	5/10/94	3.7	3.7
13/44	Barn hart	5/10/94	5/12/94	2.4	5.8
13/15	Barn hart	5/13/94	5/16/94	2.4	5.8
					avg. 4.8

Table 8. Migration days required and miles moved per day between Stanfield Dam (site 3) and ODFW (site 4). Umatilla River spring chinook salmon Passage Evaluation, 1993– 94.

Ch/Code	Rel. Site	Site 3. Date	Site 4. Date	Days	miles/day
13/14	3MD	4/20/94	4/24/94	3.9	6.1
13/16	3MD	5/9/94*	5/13/94	3.8	6.2
13/17	3MD	5/6/94	5/8/94	2.7	8.7
13/18	3MD	5/23/94	5/25/94	2	11.8
					avg. 8.2

*-estimated passage time
file name: 9394chs

Table 9. Fall chinook salmon mainstem passage data at John Day, McNary, and Ice Harbor Dams, 1990–93.

Year	Dam	Aug 1-15 No.	%	Aug 16–31 No.	%	Sep 1–15 No.	%	Sep 16–30 No.	%	Oct 1–15 No.	%	Oct 16–31 No.	%	Total No.
1990	John Day	2147	2.3	11223	12	49115	52.7	22393	24	6663	7.1	1652	1.8	93193
	McNary	2686	3.3	4504	5.5	40375	49.2	21343	26	10037	12.2	3053	3.7	81998
	Ice Harbor	102	1.9	202	3.7	1716	31.8	1598	29.6	1169	21.7	604	11.2	5391
1991	John Day	1132	1.4	3653	4.5	34358	42.7	30592	38	8434	10.5	2341	2.9	80510
	McNary	1340	1.8	2832	3.8	25055	33.9	31196	42.2	10638	14.4	2872	3.9	73933
	Ice Harbor	87	1.4	54	0.9	1989	32.5	2064	33.7	1367	22.3	563	9.2	6124
1992	John Day	1225	1.7	6320	8.6	33363	45.5	24777	33.8	6160	8.4	1413	1.09	73258
	McNary	1470	2.1	4294	6	26679	37.3	25282	35.3	11602	16.2	2280	3.2	71607
	Ice Harbor	67	1.2	156	2.8	1732	31.1	1984	35.6	1078	19.3	556	10	5573
1993	John Day	1761	2.6	8828	13	29623	43.9	22044	32.7	3805	5.6	1411	2.1	67472
	McNary	2137	3.3	6098	9.5	28042	43.6	20051	31.2	6182	9.6	1820	2.8	64327
	Ice Harbor	132	4.1	199	6.2	988	30.7	1099	34.1	539	16.7	262	8.1	3219
Total	John Day	6265	2	30024	9.5	1E+05	46.6	99806	31.7	25062	8	6817	2.2	314433
	McNary	7630	2.6	17728	6.1	12011	41.2	97872	33.5	38459	13.2	10025	3.4	291865
	Ice Harbor	388	1.9	611	3	6425	31.6	6745	33.2	4153	20.5	1985	9.8	20307

file name:chfmnstm

Table 10. Fall chinook salmon homing and straying information including percent of fish homing to the Umatilla River versus percent of fish straying into Washington fish hatcheries and spawning grounds above McNary Dam.

Recov Yr.	No. Above McNary	No. to Uma R.	% home	% stray	Total No.	avg.flow Sept 1-15	avg.flow Sept 16-31
1990	152	232	60.4	39.6	384	4	21
1991	182	145	44.3	55.7	327	50	130
1992	92	29	28.4	71.6	102	1.5	1
1993	67	44	39.6	60.4	111	78	100

Acclimated versus direct release experiments of fall chinook salmon (Table 11) show weighted average homing rates of 54.5% and 56.3% respectively. Stray rates for acclimated fish ranged from 28.6 to 75.0% while stray rates for direct releases ranged from 35.3 to 54.5%.

Table 11. Umatilla River fall chinook salmon homing and straying rates for acclimated (Minthorn) versus direct (Near Minthorn) releases.

Br.Yr.	Tag Code	Rel. Loc.	No. Tagged	Rel. Age	No. Above McNary	No. to Uma.	% home	% stray
a7	539/41	Minth	13260	0++	6	2	25	75
87	536/38	Nr. Minth	73148	0++	24	44	64.7	35.3
88	753/57	Minth	76824	0++	11	15	57.7	42.3
88	758/63	Nr. Minth	76425	0++	11	8	42.1	57.9
a9	325/27	Minth	66426	0++	2	5	71.4	28.6
a9	322/24	Nr. Minth	70450	0++	4	1	55.6	44.4
90	5563/ 5602	Minth	76411	0+	6	8 [redacted]	.1	42.9
90	560/62	Nr. Minth	73454	0+	6	5 [redacted]	5	54.5

Homing rates versus age at release for Umatilla River fall chinook salmon were greatest for age 1+ fish. Acclimated (Bonifer and Minthorn) and direct release age 1+ fish had weighted average homing rates of 62.8% with a range of 38.2 to 100% (Table 12). Homing rates for subyearling spring releases (age 0+) were 42.5% (Table 13). Fall releases of subyearlings (age 0++) were higher at 56.4% (Table 14).

Table 12. Umatilla River homing and straying data for acclimated and direct releases of age 1+ fall chinook salmon

Br.Yr.	Tag Code	Rel. Loc.	Total Rel.	Rel. Age	No. Above McNary	No. to Uma.	% home	% stray
84	3327	Bon/Minth	206815	1+	1	1	50	50
85	3823/27	Minth	109143	1+	47	29	38.2	61.8
85	3828/32	Bonifer	102363	1+	24	26	52	48
~~86~~ [redacted]	~~4038/~~ 39	M[redacted]rn	100791	1+	66	144	68.6	31.4
86	4036/37	Bonifer	99550	1+	38	92	70.8	29.2
91	146061	RM 73.5	134837	1+	0	5	100	0

Table 13. Umatilla River homing and straying data for acclimated and direct releases of age 0+ fall chinook salmon.

Br.Yr.	Tag Code	Rel. Loc.	No. Tagged	Rel. Age	No. Above McNary	No, to Uma.	% home	% stray
89	5403/05	RM 70-79	159020	0+	44	23	34.3	65.7
90	5225/5451	RM 70-79	353286	0+	21	21	50	50
90	5563/5602	Minth	76411	0+	6	8	57.1	42.9
90	5560/62	Nr. Minth	73454	0+	6	5	45.5	54.5

Table 14. Umatilla River homing and straying data for acclimated and direct releases of age 0++ fall chinook salmon.

Br.Yr.	Tag Code	Rel. Loc.	No. Tagged	Rel. Age	No. Above McNary	No. to Uma.	% home	% stray
89	5325/ 27	Minth	66426	o++	2	5	71.4	28.6
89	5322/ 24	Nr. Minth	70450	o++	4	1	20	80
87	4539/ 41	Minth	13260	o++	6	2	25	75
87	4536/ 38	Nr. Minth	73148	o++	24	44	64.7	35.3
88	4753/ 57	Minth	76824	o++	11	15	57.7	42.3
88	4758/ 63	Nr. Minth	76425	o++	11	8	42.1	57.9

Coho Salmon

Coho salmon counts at John Day Dam peak during the last two weeks of September. Although Columbia River entry for coho salmon is later than that for fall chinook salmon, entry timing at Three Mile Falls Dam is similar. In 1991, 1992 and 1993, significant numbers of coho began entering the Umatilla River once flows reached 150 cfs (Appendix A, Figures A-5 to A-7).

Consistent with what Kissner (1992) reported, large numbers of coho salmon released in the Umatilla River ultimately return to their rearing facility at Bonneville Complex. Stray rates above McNary Dam are essentially zero (Table 15). Homing rates for coho salmon during the 1988-1992 return years have ranged from a high of 96.4% in 1989 to a low of 57.2% in 1991. Weighted average homing and straying rates are 85.4% and 14.6% respectively.

Table 15. Coho salmon homing and straying information including number of fish returning to the Umatilla River verus number of fish straying to Bonneville Complex and above McNary Dam.

Recovery Yr.	No. to Uma.	No. to Cascade	No. to other	No.above McNary	% home	% stray	total
88	125	12	1	1	90.6	9.4	138
89	533	16	4	0	96.4	3.6	553
90	115	41	2	0	72.8	27.2	158
91	190	97	45	0	57.2	42.8	332
92	20	2	0	0	90.9	9.1	22

Weighted average homing rates to the Umatilla River for acclimated versus direct releases of coho salmon were 70.4% and 72.1% respectively (Table 16).

Table 16. Umatilla River homing and straying rates for acclimated and direct releases of coho salmon (includes acclimation/evaluation experiments).

Br.Yr	CWT No.	No. Tagged	Rel.Loc.	Stray No.	Home No.	% stray	% home	total No.
87	074609	27062	Nr. Minth	4	19	17.4	82.6	23
87	074610/11	53155	Minth	20	75	21.1	78.9	95
88	074814	28033	Minth	48	81	37.2	62.8	129
88	074813	26881	RM 63-70	36	72	33.3	66.7	108
a9	075535	24584	Minth	0	6	0	100	6
89	075534	25338	RM 56-60	3	8	27.3	72.7	11
89	075533	25407	RM 63-70	0	12	0	100	12

Summer Steelhead

Coded wire tag data analyzed by Kissner (1992), found summer steelhead in the mainstem Columbia River (Zone 6) from August 1 through October 31. Entry timing at Three Mile Falls Dam varies greatly and often extends over several months. Generally, the largest number of fish enter the Umatilla River in February, March, and April. However, large numbers of summer steelhead have been seen in November and early December.

Data does not suggest that summer steelhead are straying. Coded wire tag data analyzed by Rowan (1994) uncovered only one coded-wire tagged Umatilla River origin summer steelhead above McNary Dam. Umatilla River summer steelhead have been shown, however, to migrate over McNary Dam prior to falling back and ascending the Umatilla River (Wagner 1990, 1991).

In general, significant numbers of summer steelhead enter the Umatilla River when flows exceed 500 cfs (Appendix A, Figures A-8 to A-11) although flows exceeding 1,000 cfs have been required in the last three return years. Temperatures less than 40 degrees fahrenheit delay entry. An example of this can be seen in late December and early January, 1990-91 (Appendix A, Figures A-8 and A-12). Flows during this period were greater than 3,000 cfs. Temperatures, however, were less than 35 degrees fahrenheit.

Spring Chinook Salmon

Spring chinook salmon migration in the Umatilla River begins in early April and generally peaks in mid-May. Unlike fall chinook salmon, entry at Three Mile Falls Dam does not closely correspond to increases in attraction flows (Appendix A, Figures A-13 to A-16). In 1993, flows exceeding 2,000 cfs were required to encourage entry while only 200 cfs was required in 1992 (Appendix A, Figures A-14 and A-15).

Stray rates for Umatilla River spring chinook salmon have remained low. Coded-wire tag data associated with homing rates for the 1989-1993 return years have ranged from 94.8% in 1992, to 100% in 1989 (Rowan, 1994). Radio telemetry data, however, has demonstrated Umatilla River origin spring chinook salmon migrate above McNary Dam. In 1993, six adult spring chinook salmon radio-tagged at John Day Dam (Columbia River) entered the Umatilla River and were recaptured at Three Mile Falls Dam. Data collected during recapture allowed CTUIR to receive original tagging dates and mainstem migrational patterns following release at John Day Dam. Five of six fish monitored migrated either up to, or above, McNary Dam prior to falling back and entering the Umatilla River (Table 17).

Table 17. Mainstem migrational patterns and range of flows exiting the Umatilla River between release date (at John Day Dam) and recapture date (at Three Mile Falls Dam) for Umatilla River spring chinook salmon tagged by the University of Idaho Cooperative Fish and Wildlife Research Unit at John Dav Dam (Columbia River) 195 3.

Channel	Code	JDD Date	3MD Date	Days to 3MD	Mainstem Movements	Range of Flows Uma.R
12	43	4/30/93	5/12/93	12	2 McNary May 3, 1993 1 McNary May 7, 1993	2,071-9,170
5	18	4/26/93	5/14/93	18	1 McNary May 4, 1993	1,684-9,170
7	46	4/26/93	5/14/93	18	1 McNary May 5, 1993	1,684-9,170
6	42	5/17/93	6/8/93	22	1 McNary May 29, 1993 2 McNary June 2, 1993	128-611
4	19	4/28/93	5/12/93	14	2 McNary Apr 30, 1993 S. Shore Ice Harbor May 3, 1993	1,709-9,170

1 McNary = Southshore Ladder
2 McNary = Northshore Ladder

DISCUSSION

Radio Telemetry-Passage Evaluation

Fall Chinook and Coho Salmon

Tagging activities at Three Mile Falls Dam did not commence until late October. By this time, coho and fall chinook were in advanced stages of spawning and thus poor physical condition. Telemetry data collected for these fish is indicative of late-returning fish and does not accurately portray the entire migrational period. Because of this, very little telemetry-related text is included regarding these species. An accurate picture of the migrational movements of these fish should include a larger percentage of the population throughout the migrational return.

Summer Steelhead

Average time needed to migrate through the diversion areas was highly variable. To say that all summer steelhead require two weeks to successfully migrate from Three Mile Falls Dam to above Stanfield Dam is inaccurate. Migration through the diversion areas (Three Mile Falls Dam to Stanfield Dam) ranged from a high of 120 days to a low of two days. This information reflects the magnitude of trap and haul management decisions. Decisions concerning transport of adult salmonids should reflect not only flow forecasts, but also time of year and species in question.

Data did not suggest that migrational delays at Feed Canal Dam were in response to flow problems, though low flows (less than 200 cfs) were not encountered during passage. Feed Canal Dam was designed for water diversion, not fish passage. The large apron on the downstream side of the dam creates false attraction for ascending adults and prevents fish from easily jumping over the crest of the dam. Surprisingly, nearly half (47%) of the fish encountering the dam were able to successfully "jump" over the structure because of small pools created at either end of the dam.

Although avoidance of fish ladders, and thus delay, has been documented on other systems (Bjornn, et. al 1992), data did not suggest this was occurring at Feed Canal Dam. Rather, it appears summer steelhead are unable to locate the ladder entrance. The large expanse of the dam relative to the small fish ladder entrance is likely responsible. Strong attraction flows toward the fish ladder may help alleviate this problem. This, however, would only be a solution during low flows. During high flows, water spills over the entire crest, thus creating false attraction and again delay.

The effect of delay below Feed Canal Dam on upstream migrants is unknown. For summer steelhead returning early in the migrational period, a small delay is probably insignificant. Late returning steelhead, however, and also spring chinook, fall chinook, and coho salmon may be influenced. Timing for these fish is critical. Migrational delay and repeated attempts to negotiate the structure may be tapping into vital energy reserves and causing physical damage to these fish. This, in-turn, may promote pre-spawn mortality and impact distance migrated and spawning sites chosen.

Figure two illustrates that it is not the reach of river causing delay but rather the diversion dams within the reach. Clearly, summer steelhead had no trouble ascending sections of the river without diversion dams. Once encountering sections with dams, migrational movements were considerably reduced. It is interesting to note that summer steelhead appear willing to migrate at marginal water temperatures (40 to 43 degrees fahrenheit) through sections of the river without diversion dams, but upon encountering sections with dams, migration either stops or passage time increases.

Several solutions concerning the delays at Feed Canal Dam have been suggested. These include spill gates near the north shore (right bank) and additional jump pools on the south shore. Spill gates are likely the best short-term remedy and would effectively promote attraction flows towards the fish ladder and headworks of the irrigation canal. This in turn would help create a more substantial channel along the north bank which should enhance migration towards the fish ladder.

Spring Chinook Salmon

CTUIR intended to radio tag 20 spring chinook salmon for passage evaluation. Low flows, and poor return numbers precluded this goal. Passage data in 1994 was derived from five fish. Although delays were not seen at Stanfield Dam, some delays were observed at Feed Canal and Westland dams. Delays below Westland Dam were primarily in response to flows. Average passage time at Westland was 9:14 for spring chinook, compared to 1:30 for summer steelhead. Flows ranged from seven to 2,070 cfs, with all migrational delays occurring at flows less than 200 cfs. Inadequate attraction flows exiting the fish ladder in conjunction with impaired jumping capabilities (flashboards) are likely responsible.

Similar to summer steelhead, increased passage time for spring chinook salmon at Feed Canal Dam did not appear to be flow-related (flows during evaluation ranged from 346 to 1,563 cfs). Average migrational passage time for spring chinook at Feed Canal Dam (11:58) was considerably less than observed for summer steelhead (48:54). Favorable water temperatures, flows, and a greater ability to jump the structure may explain the difference. Four (out of five) fish chose to jump the structure in 1994. This does not suggest that spring chinook are without migrational difficulty at Feed Canal Dam. Passage times at Feed Canal are more than 10 times greater than those observed at Stanfield Dam. Large delays were observed for spring chinook salmon at Feed Canal Dam during the 1993 passage evaluation. Without facility modifications at Feed Canal Dam, delay will continue.

Upstream Transport Evaluation

Summer Steelhead and Spring Chinook Salmon

Movements of summer steelhead following upstream transport were optimistic. Of those providing data (eight fish), all demonstrated upstream migration following release at either Nolin or Barnhart. It was suspected that transported fish would go through an acclimation period, either holding or falling back a short distance prior to resuming upstream migration. This behavior did not transpire. Migrational rates through the same section of river were nearly identical for fish transported (6.2 miles per day) versus those released at Three Mile Falls Dam (6.0 miles per day). In general, transported fish were at least one mile above the liberation site within 24 hours of release.

Results for transported spring chinook salmon were similar to those observed for summer steelhead. Following release at either Barnhart, Thornhollow, or Imeques-C-mem-ini-kern, immediateupstream migration occurred for all fish (eight provided data). Although the small sample size may help explain the discrepancies, it is unknown why migrational rates of fish transported versus those released at Three Mile Falls Dam were not as similar as those observed for summer steelhead.

In recent years, adult counts on spawning surveys in relationship to release numbers at Three Mile Falls Dam have suggested that fish may be falling back into the lower Umatilla River. As recent as 1993, an estimated 43% of the spring chinook salmon released above Three Mile Falls Dam were unaccounted for (CTUIR 1994). More data concerning the movements of transported salmonids is needed. The implications of this information may have significant use as a management tool concerning trap and haul procedures.

Homing and Passage Needs in the Umatilla River

Entry timing for summer steelhead at Three Mile Falls Dam can begin as early as late August and extend into late May. Native summer steelhead have managed to survive in the Umatilla River because of their ability to wait long periods of time, if necessary, between mainstem entry (Columbia River) and spawning (Kissner 1992). Stray rates associated with summer steelhead are extremely low. Unlike indigenous salmon, summer steelhead migrating above McNary Dam typically have several months to fall back, relocate, and successfully ascend the Umatilla River.

Large attraction flows are required to "pull" significant numbers of summer steelhead into the Umatilla River. Flows exceeding 500 cfs are required in most cases and as much as 1,500 cfs in some years. This does not suggest migrational entry will not occur at flows less than 500 cfs. Summer steelhead will enter the Umatilla River under low flow conditions, but given the choice, most enter during moderate to high flows.

Entry for fall chinook salmon at Three Mile Falls Dam hinges on availability of attraction flows. Without attraction flows at or near the mouth of the Umatilla River in late August and early September, straying and late entry of fall chinook salmon is inevitable. Phase I provided minimum flow levels below Three Mile Falls Dam in 1993. These flows, however, were less than 100 cfs. Despite additional flow, homing and straying rates of fall chinook salmon in 1993 remained similar. Data clearly demonstrates that at least 150 cfs is required to encourage movement of both fall chinook and coho salmon into the Umatilla River.

Regardless of attraction flow levels, it may be discovered that some fall chinook salmon naturally migrate upstream of the mouth of the Umatilla River. Migrational behavior of this type has been clearly documented for both Umatilla River origin summer steelhead and spring chinook salmon (discussed earlier) at attraction flows far exceeding those experienced during the fall chinook salmon migration (Wagner 1990.). Fall chinook salmon above the mouth of the Umatilla River, may simply be "testing" for Umatilla River water with the intention of dropping back if the Umatilla River is not detected. Once over McNary Dam however, they find passage back through the dam difficult and thus spend days if not weeks in the McNary pool and forebay before successfully falling back and entering the Umatilla River. Typically, a Umatilla River origin fall chinook salmon above McNary Dam is considered to be straying. In reality, this may be a natural part of the migrational process of these fish.

It would be interesting to see migrational entry dates of fall chinook salmon at flows exceeding 500 cfs beginning in early September. Given these conditions, mainstem migrational straying and thus delay may be significantly reduced. Some might argue that historical flows at the mouth of the Umatilla River in early September were not 500 cfs. Historically, however, the Columbia River was not a reservoir as it is today. Lake-like conditions and thus poor water mixing in the mainstem may demand attraction flows far greater than previously required. Until migrational entry at various attraction flows is understood, minimum attraction flows should not be set.

Recommendations:

Install spill gates and jump pool(s) at Feed Canal Dam. This will reduce passage time for upstream migrating adult salmonids. At minimum, spill gates should be in place prior to the 1994 arrival of fall migrating salmonids. Passage data will effectively evaluate the level of success concerning any facility modifications.

Plans for the 1994-95 Adult Passage Evaluation

Radio telemetry is providing valuable information regarding the migrational movements of adult salmonids in the Umatilla River. CTUIR intends to conduct a study similar in size and scope to the study conducted during the 1993-94 return period. Migrational patterns following release at Three Mile Falls Dam will be evaluated for all four species of anadromous salmonids in the Umatilla River. Summer steelhead and spring chinook salmon will be evaluated following upstream transport. Fixed-site receivers will be installed at Westland, Feed Canal, and Stanfield dams. An additional receiver will be in place at the Oregon Department of Fish and Wildlife (ODFW) Office in Pendleton, Oregon. Greater effort will be given to increase the sample size for both evaluations.

Acknowledgements

The author would like to thank the following people for their efforts toward the success of the 1993-94 adult passage evaluation. Robert Quaempts for assisting in all field related aspects of the project; Larry Cowapoo, Brian Conner, Vern Spencer, Brent Spencer, Louis Case, and Bill Duke (ODFW) for assistance during tagging and release efforts at Three Mile Falls Dam; Gerald Rowan for the coded- wire tag information and Brian Zimmerman and Bill Duke for the temperature and flow data. I would also like to thank Gary James, fisheries program manager, for project management, assistance and critical review; Joe Richards, Department of Natural Resources Administrator for contract administration, and fisheries secretaries Julie A. Burke and Celeste Reves for assistance in report preparation. Additional thanks to all USBR employees involved with the operation and maintenance of Three Mile Falls, Westland, Feed Canal, and Stanfield dams.

The author appreciates the efforts of Suzanne Knapp of the Oregon Department of Fish and Wildlife in contract and report preparation and Jay Marcotte and Jerry Bauer of the Bonneville Power Administration for their assistance with contract funding.

References

Bjornn, T.C., R.R. Ringe, K.R. Tolotti, P.J. Keniry, and J.P. Hunt 1991. Migration of adult chinook salmon and steelhead past dams and through reservoirs in the lower Snake River and into tributaries. Report prepared for U.S. Army Corps of Engineers.

Confederated Tribes of the Umatilla Indian Reservation, 1994. Umatilla Basin natural production monitoring and evaluation annual progress report, 1992-93. Report submitted to Bonneville Power Administration, Project No. 90-005-01.

Kissner, Paul D. 1993. pp. 49-97 in S. M. Knapp, editor. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions in the Umatilla River. Report submitted to Bonneville Power Administration, Project No. 83-435. 107pp.

Nielson, Reed S. 1950. Survey of the Columbia River and its tributaries. Report prepared for the United States Department of the Interior, Report No. 38.

Rowan Gerald D. 1994. Minthorn Springs Creek summer juvenile release and adult collection facility. Report submitted to Bonneville Power Administration, Project No. 83-435.

Wagner, Paul G. 1990. Evaluation of the use of the McNary bypass system to divert adult fallbacks away from turbine intakes. Contract No. DACW68-82-C-0077.

Wagner, Paul G. and Todd Hillson. 1991. Evaluation of adult fallback through the McNary Dam juvenile bypass system. Report prepared for U.S. Army Corps of Engineers, Contract No. DACW68-82-C-0077.

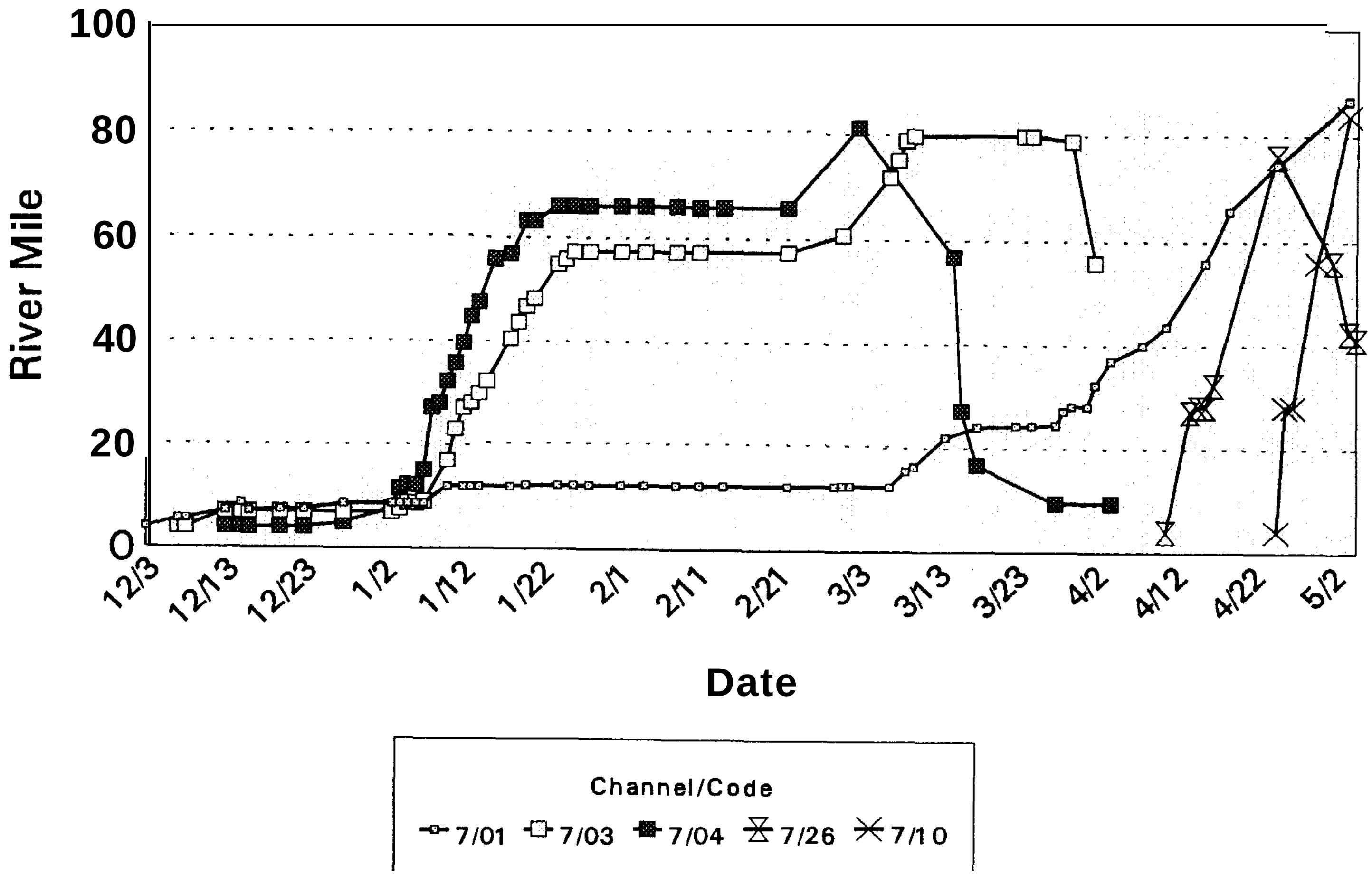
Zimmerman, Brian C., and Bill B. Duke. 1994. Trapping and Transportation of adult and juvenile salmon in the Lower Umatilla River in Northeast Oregon. Report submitted to Bonneville Power Administration, Project No. 88-022. 46pp.

APPENDIX A

Migrational Behavior, Passage Times, and Homing Versus River Flow for Adult Salmonids in the Umatilla River

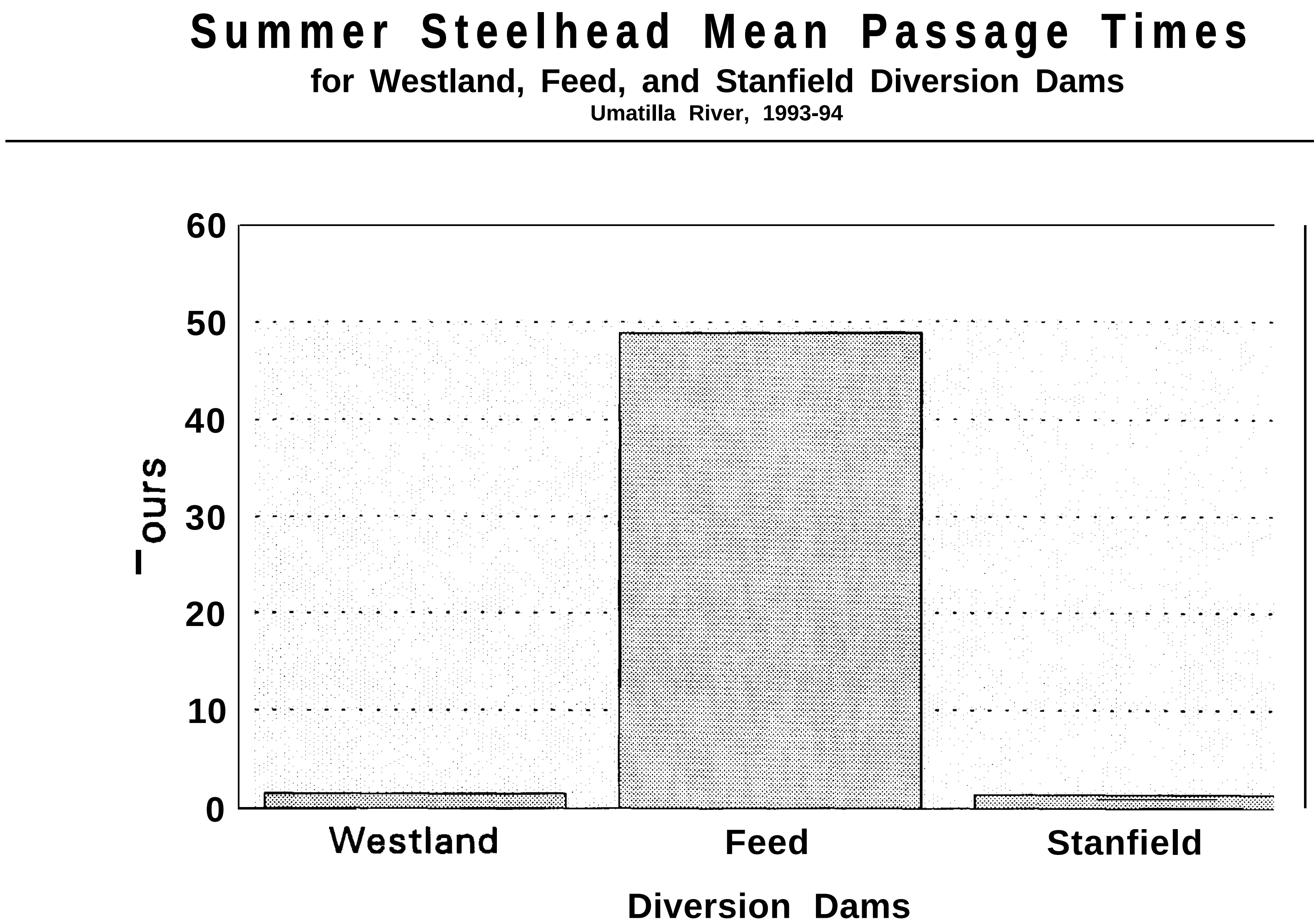
Appendix Figure A-l

Summer Steelhead Migrational Behavior
Umatilla River 1 993-94



Passage Evaluation
Release site RM4-3MD
File Name sts9394

Appendix Figure A-2

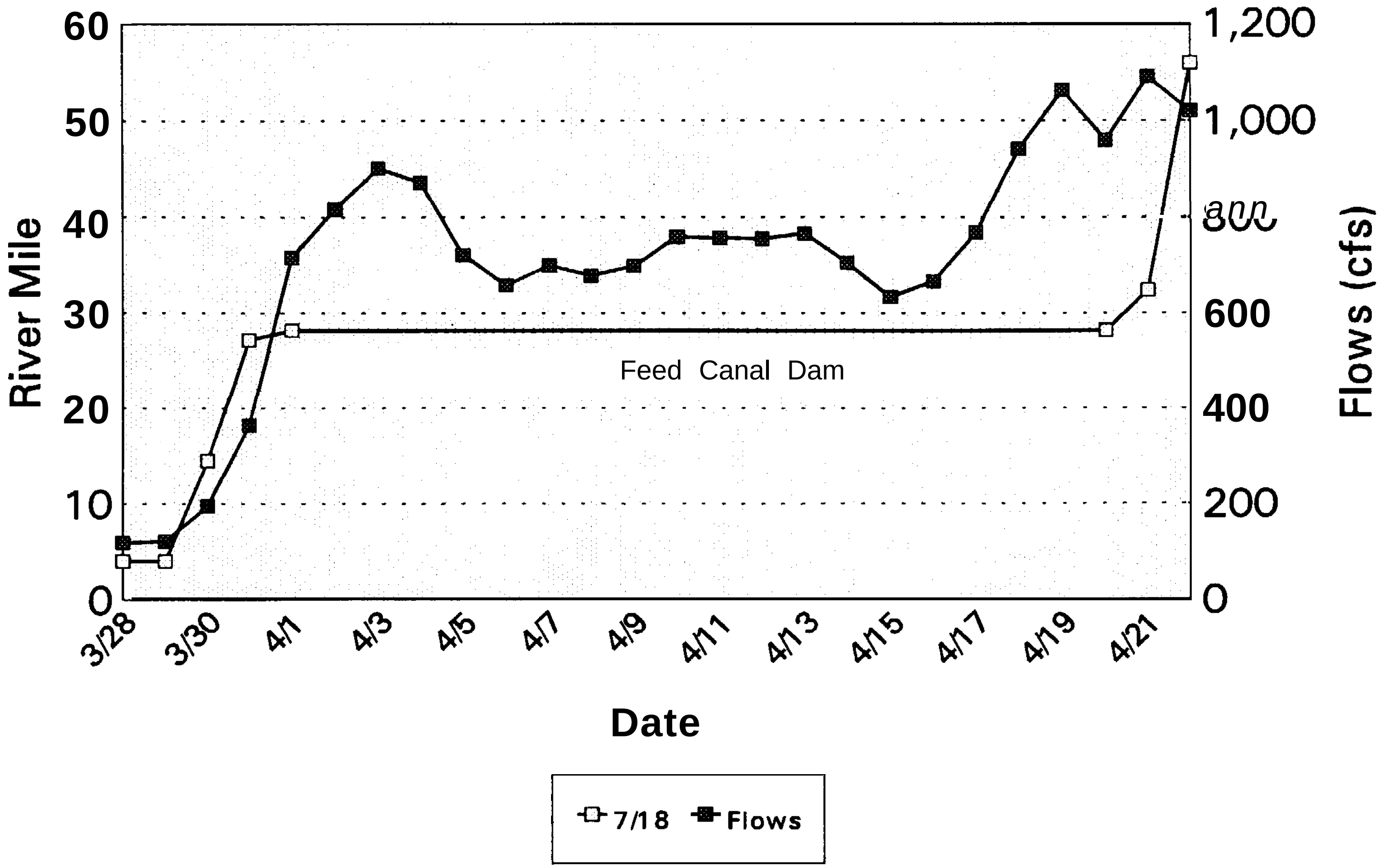


Westland-1:30
Feed-48:54
Stanfield-l :23 (file name avgpass)

Appendix Figure A-3

Summer Steelhead Migrational Behavior vs Flows

Umatilla River 1993-94

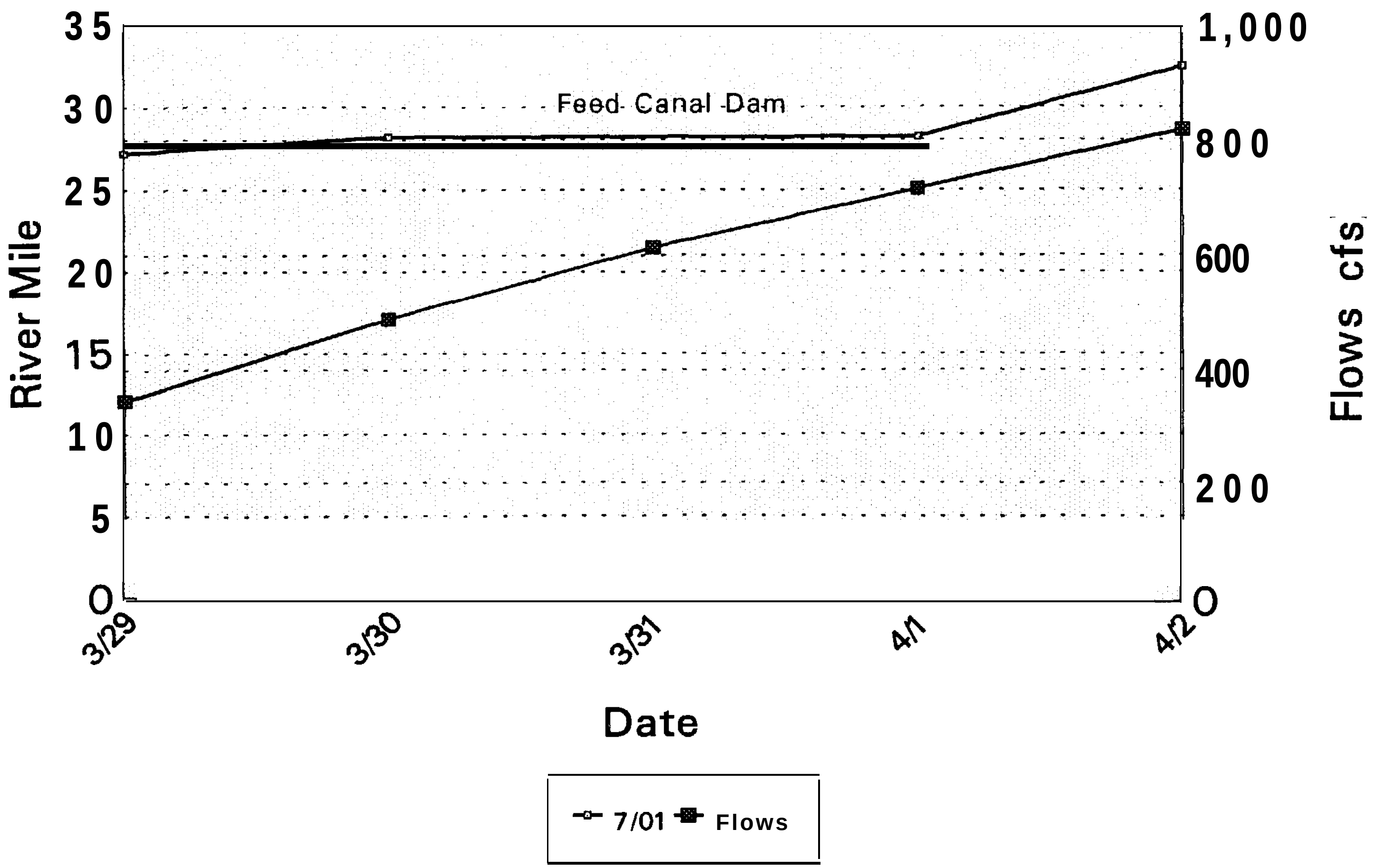


Passage Evaluation
Release site RM4-3MD
File Name stsflw3

Appendix Figure A-4

Summer Steelhead Migrational Behavior vs Flows

Umatilla River 1993-94

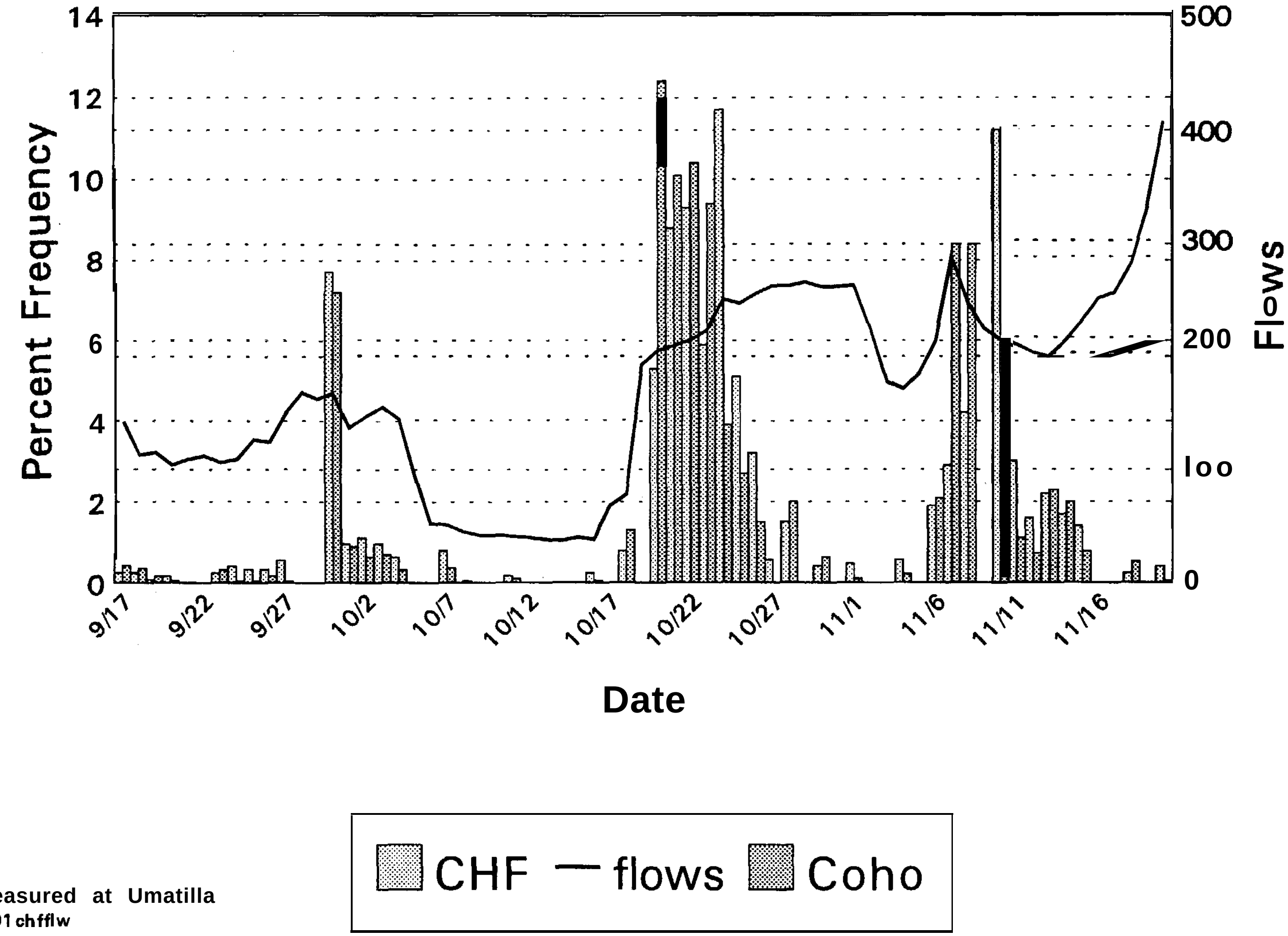


Passage Evaluation
Release site RM4-3MD
File Name stsflw6

Appendix Figure A-5

Fall Chinook and Coho Returns Versus Flows

Umatilla River 1 991

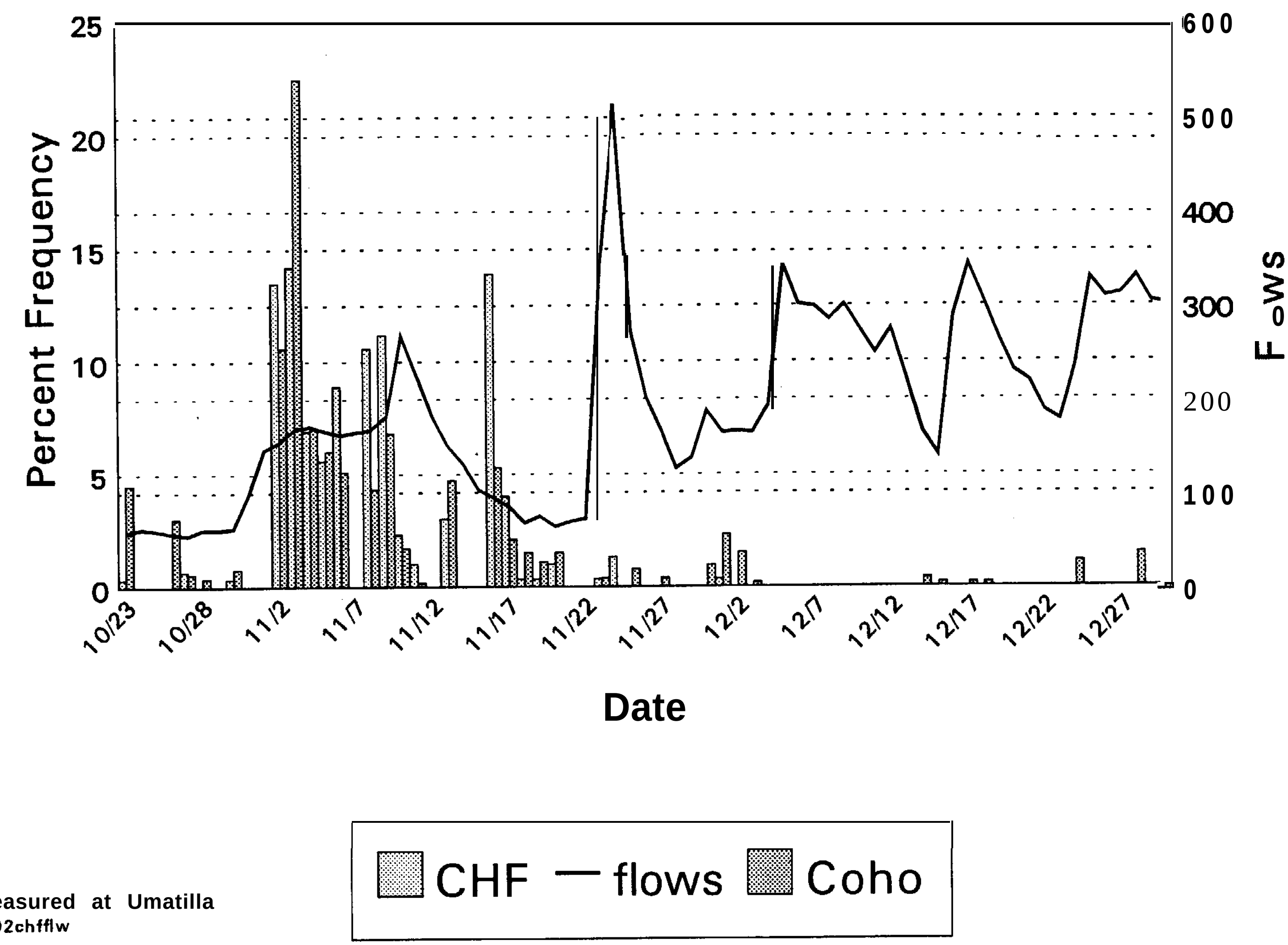


Flows measured at Umatilla
File name; 91chfflw

Appendix Figure A-6

Fall Chinook and Coho Returns Versus Flows

Umatilla River 1992

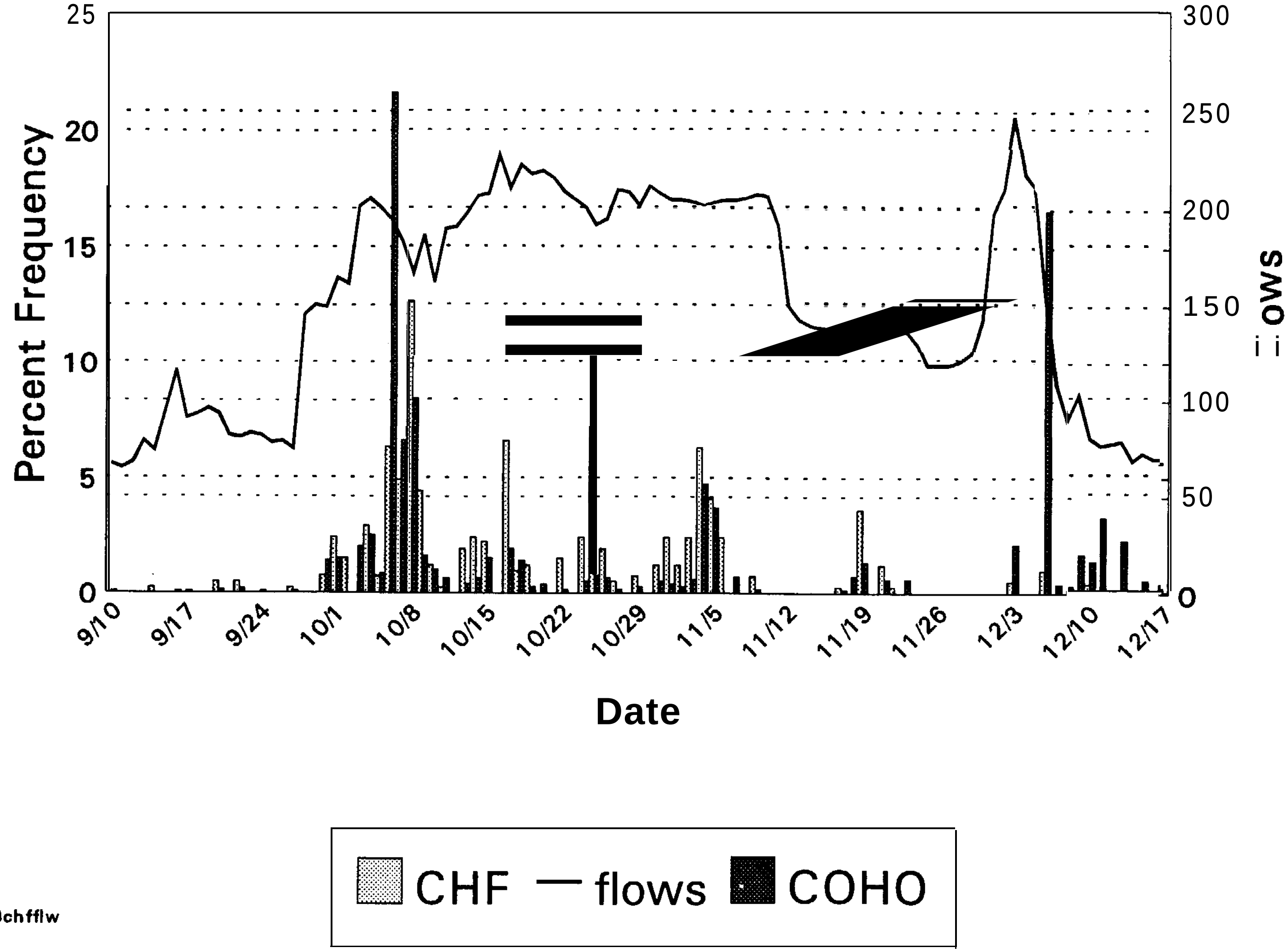


Flows measured at Umatilla
File name: 92chfflw

Appendix Figure A-7

Fall Chinook and Coho Returns Versus Flows

Umatilla River 1993

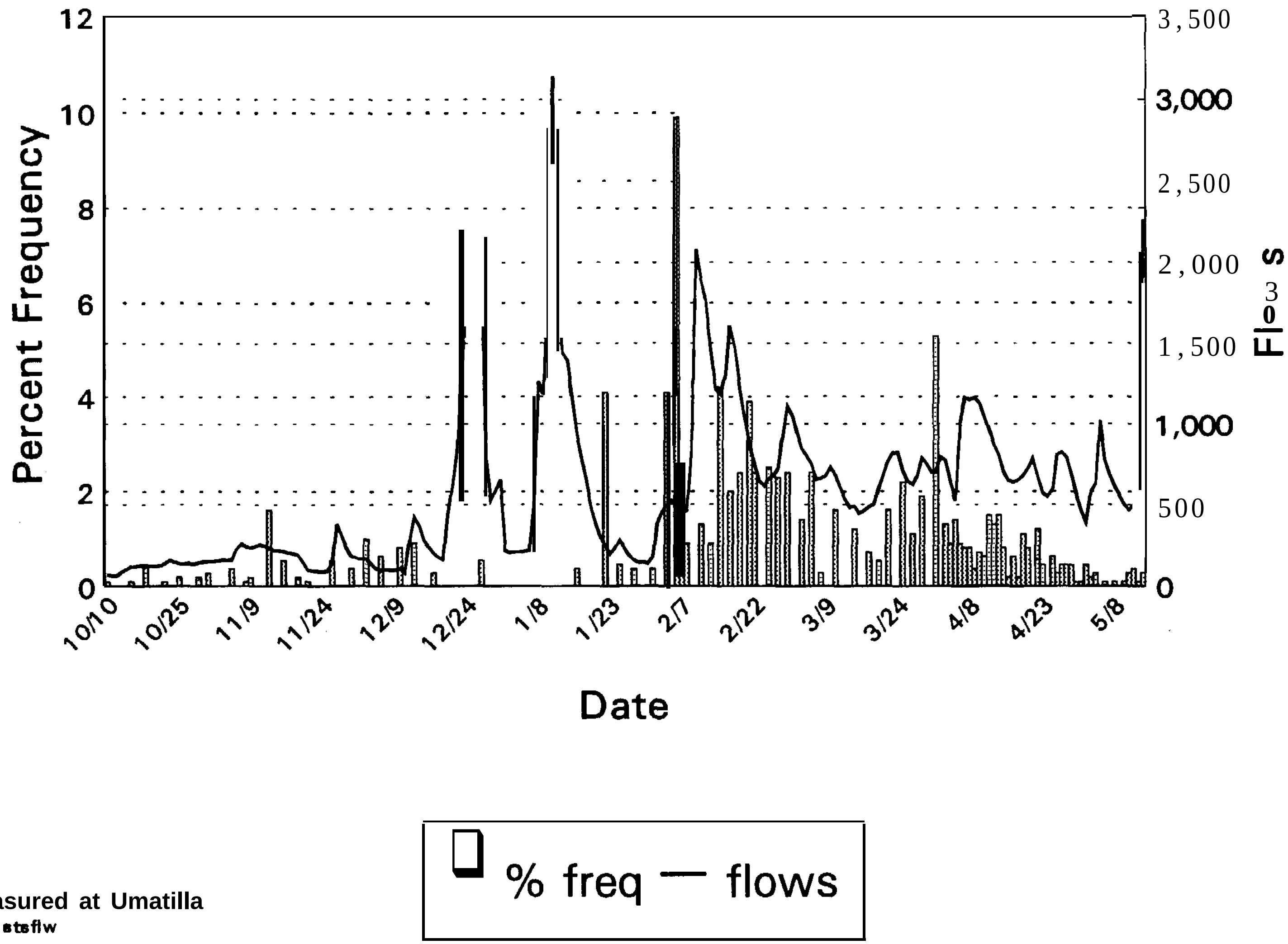


File name: 93chfflw

Appendix Figure A-8

Summer Steelhead Returns Versus Flows

Umatilla River 1 990-91

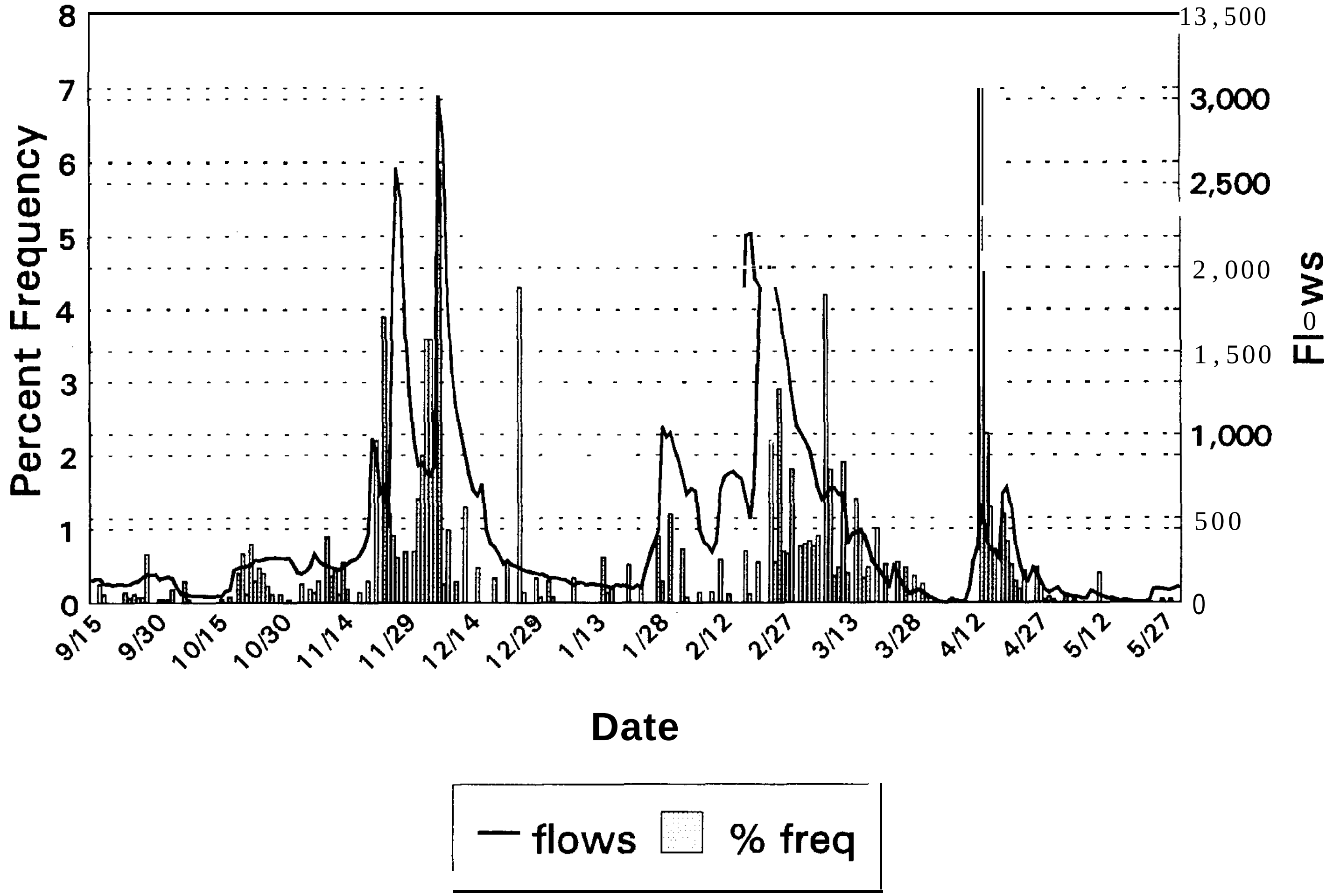


Flows measured at Umatilla
File name: 91 stsflw

Appendix Figure A-9

Summer Steelhead Returns Versus Flows

Umatilla River 1991-92

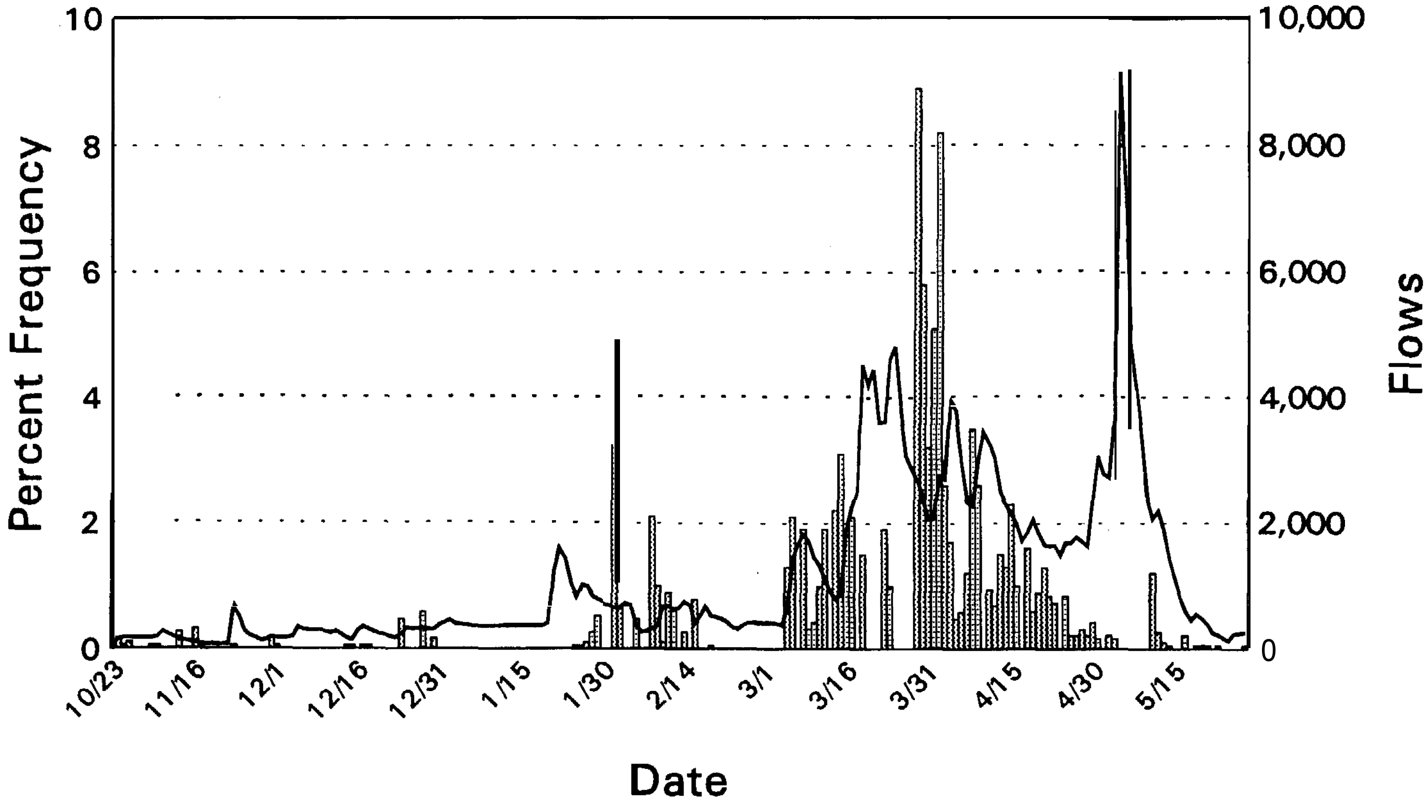


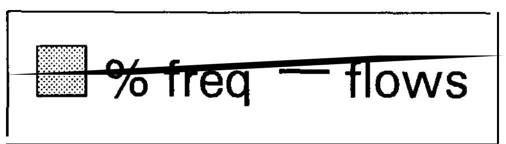
Flows measured at Umatilla
File name; 92stsflw

Appendix Figure A- 10

Summer Steelhead Returns Versus Flows

Umatilla River 1992-93



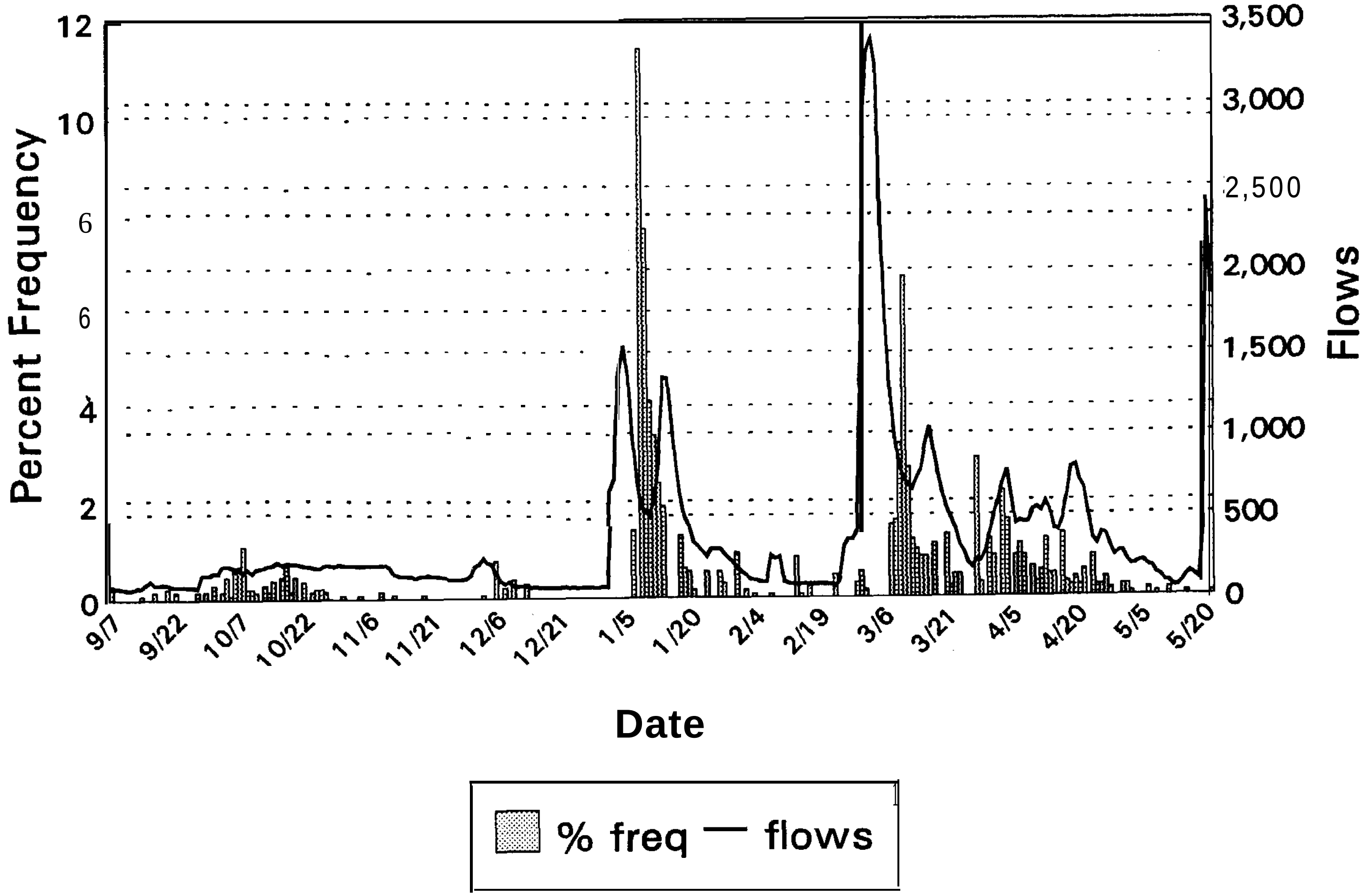


Flows measured at Umatilla
File name: 93stsflw

Appendix Figure A- 11

Summer Steelhead Returns Versus Flows

Umatilla River 1993-94



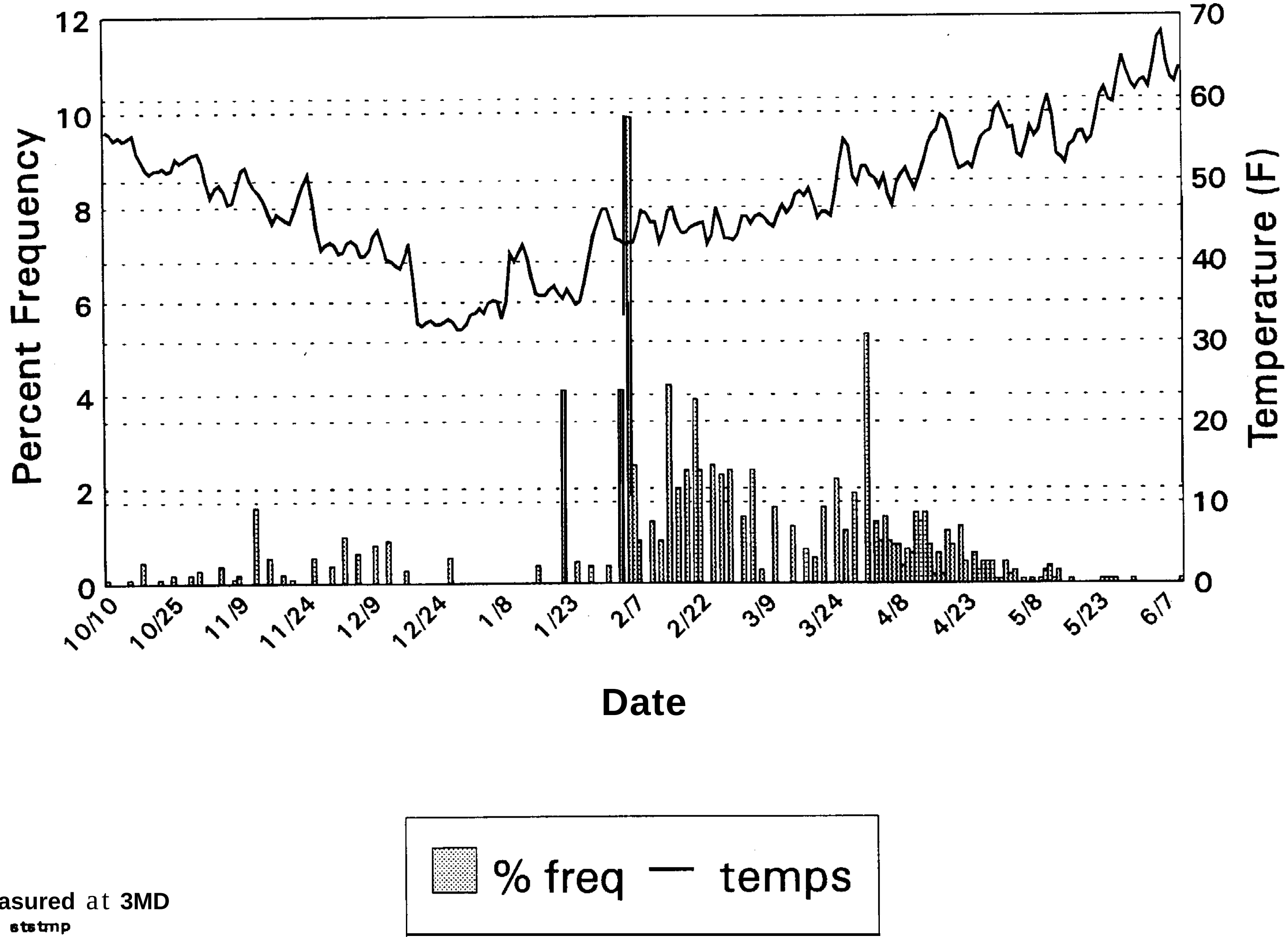
Three Mile Falls Dam

File name: 94rtrflw

Appendix Figure A- 12

Summer Steelhead Returns Versus Temps

Umatilla River 1990-91



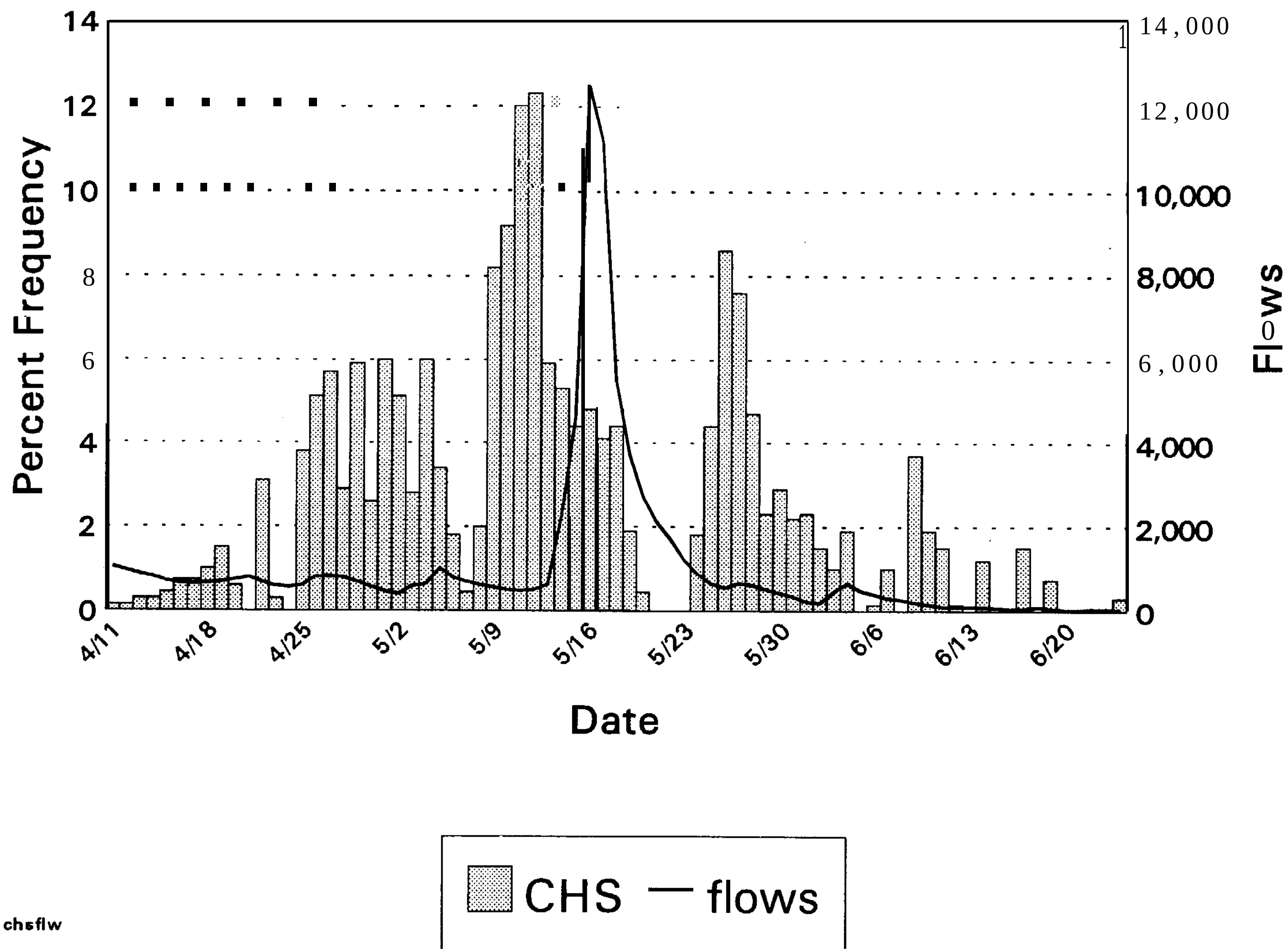
Temps measured at **3MD**

File name: 91 ststmp

Appendix Figure A- 13

Spring Chinook Salmon Versus Flows

Umatilla River 1 991

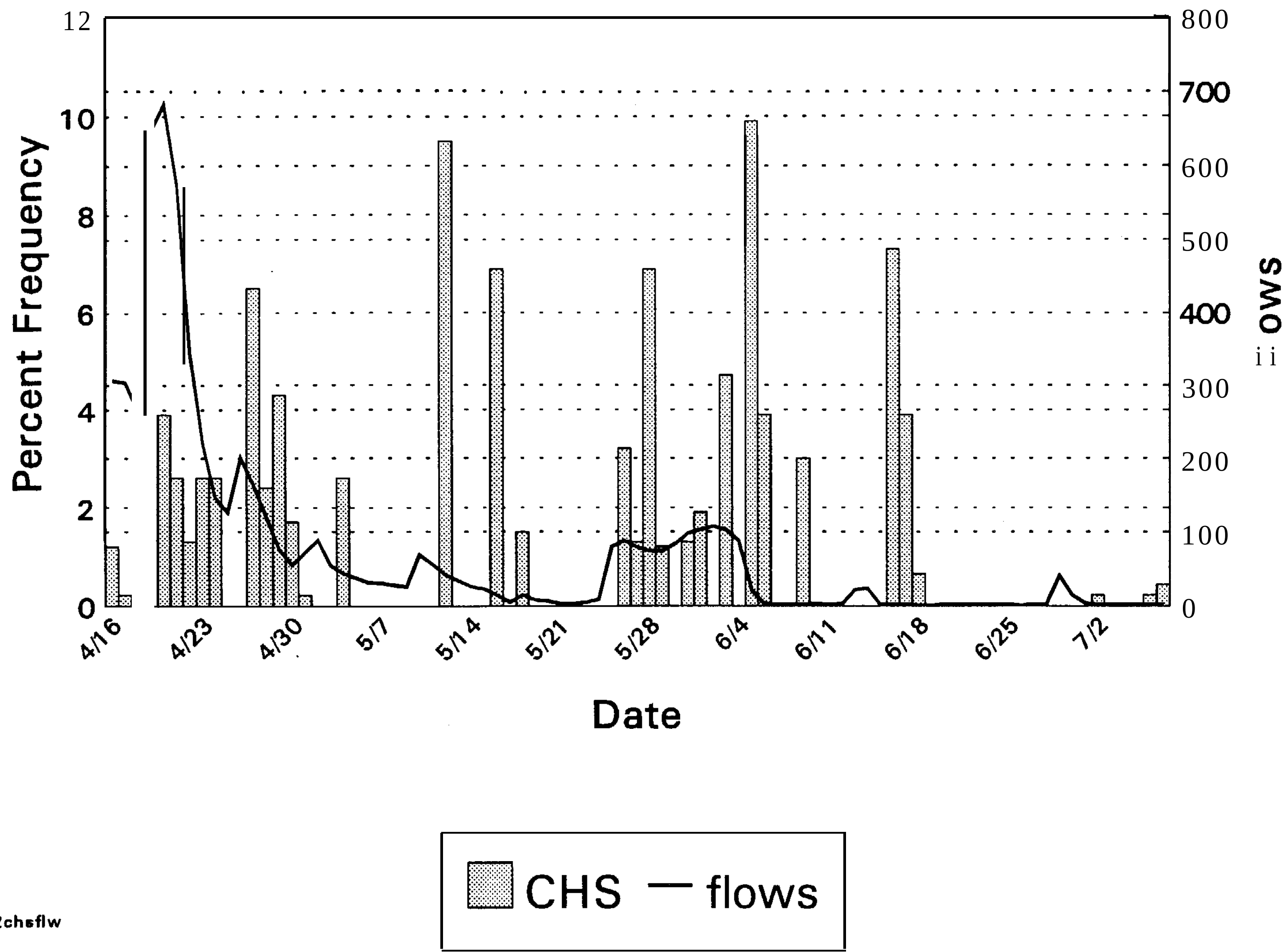


File name: 91 chsflw

Appendix Figure A- **14**

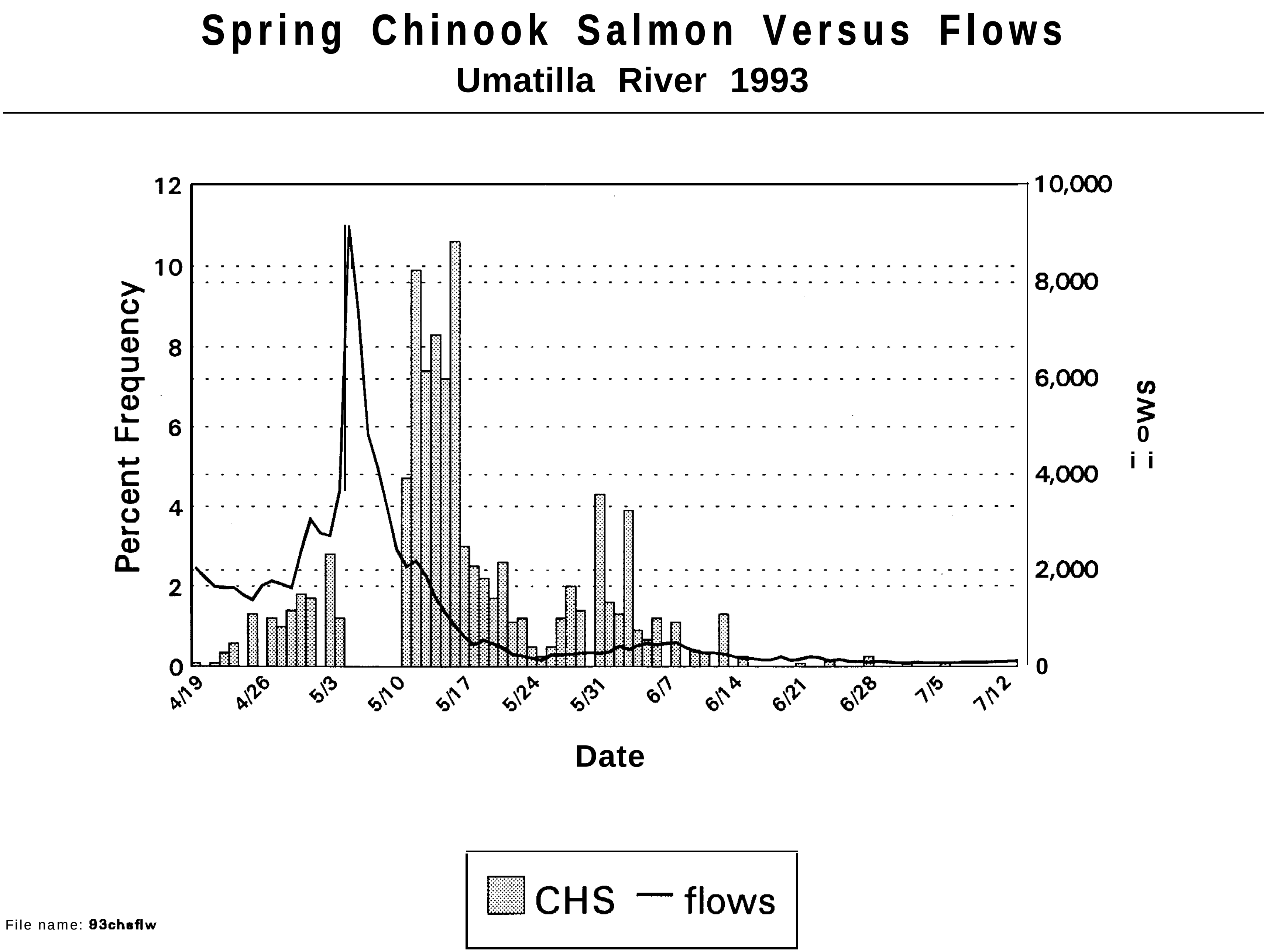
Spring Chinook Salmon Versus Flows

Umatilla River 1992



File name: 92chsflw

Appendix Figure A- 15

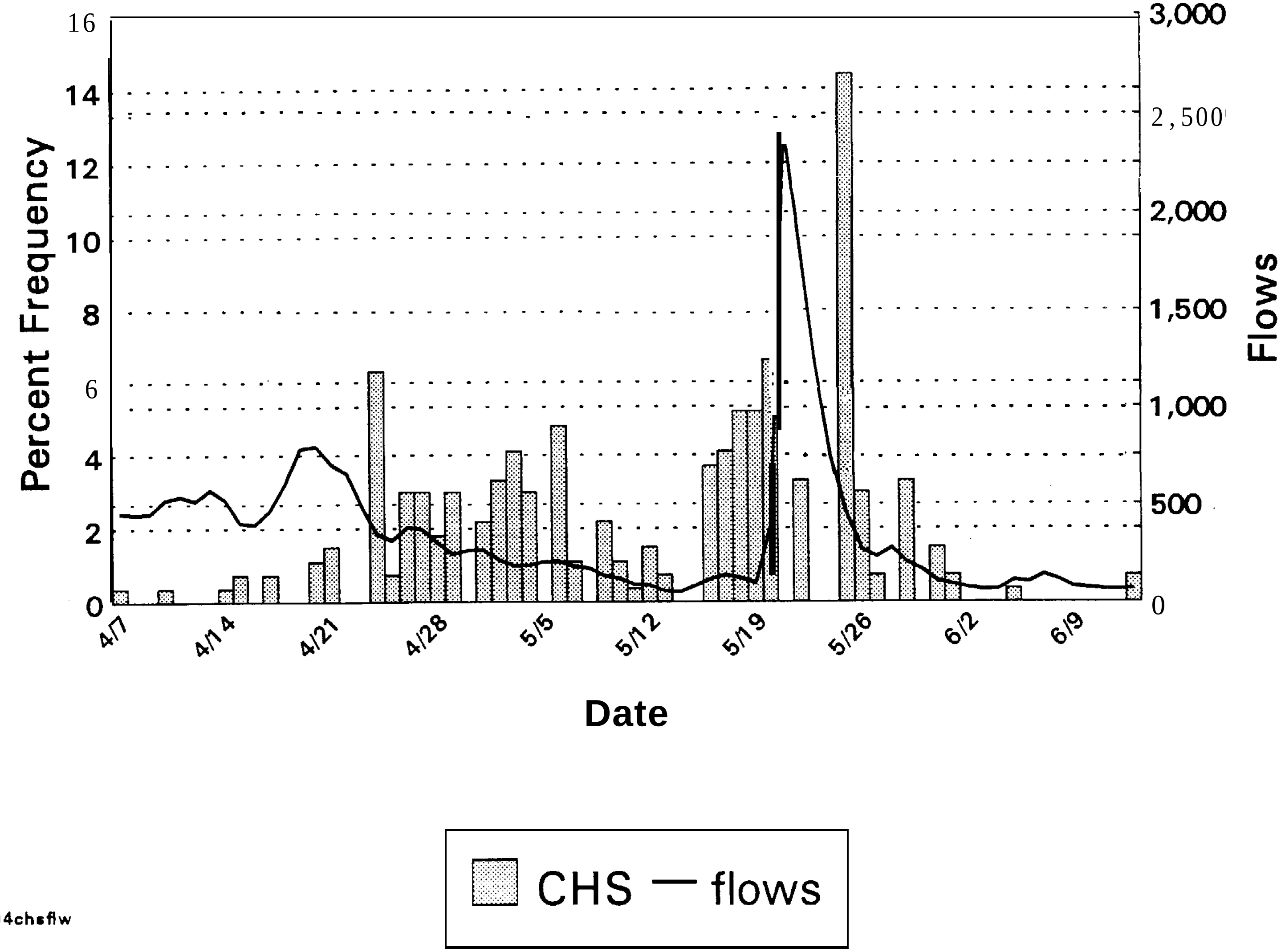


File name: **93chsflw**

Appendix Figure A- 16

Spring Chinook Salmon Versus Flows

Umatilla River 1994



File name: 94chsflw

DOE/BP-01385-5
May 1995
775